Indian Himalayas
An Integrated View

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Jagdish Bahadur

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VIGYAN PRASAR

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Dedicated to the fond memory of my beloved parents who always kindly supported me and my activities.

इदाह्नः पीतिमुत वो मदं धुर्न ऋते श्रान्तस्य सख्याय देवाः।
ते नूनमस्मे ऋभवो वसूनि ततीय अस्मिन् त्सवने दधात ॥

The dedicated men offer love and respect
To the cosmic divinities;
But remember, offering love alone
is not enough;
Constant hard work and diligence
Are essential for success.
Then alone the Lord Supreme
Showers His blessings upon them

Rig Veda

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FOREWORD

The Himalayas occupy a special status for our environment. It is our country's pride and a symbol of value system. The mountain system needs to be preserved, sustained and nurtured to keep up its grandeur. In general, the science and technology holds a key to socio-economic development and should be utilized to better the quality of life in fragile Himalayan region. There is need to have a well- thought, integrated and coordinated approach involving various stakeholders for sustainable development of the region. The development of the region is intimately connected with the maintenance of the granary of Indo-Gangetic plains – the grain bowl of the country.

The Department of Science and Technology has supported the development of the region since its inception. It organized a national seminar on resource development and environment in the Himalayan region from 10-13 April, 1978 at Vigyan Bhavan under the guidance of distinguished agricultural scientist, Professor B.P. Pal, FRS. The Department has provided major support to nationally coordinated programme on Himalayan Seismo-tectonics since 1982; Himalayan Glaciology since 1984; Conceptualization of a National Board for Mountain Research and Technology Development following the Indian Science Congress in 1985 and Landslide Project since 1989. It supported a brain-storming session on Himalayan Experiment (HIMEX) in 1995 at IIT Delhi which recommended that the emphasis be paid to snow monitoring, mountain meteorology and establishment of bio-geodata bases for each district of the mountain region for sustainable development. During March 1999 another brain-storming meeting on Bio-geodata Base and Ecological Modeling for Himalaya was sponsored at the India International Centre with theme lectures on land-use and sustainable development, Himalayan glacial system, geological fragility, eco-rehabilitation, soil resources, thematic mapping, natural resource accounting, remote sensing and hydrological modeling, followed by a workshop having discussions on climate and Himalaya, paleo biodiversity, weather systems and forecasting, natural resource management and integrated development

for Himalaya. Another three-day workshop was organized in April, 2000 on the role of science and technology in the integrated development of Uttaranchal at Almora. During March 13-15, 2002, an Indo-Central Asian Republics Glaciologist's workshop was organized at India International Centre for developing a joint collaborative programme in the field of glaciology for monitoring the role of snow and ice in Himalayas.

As development of Himalayan region is very difficult and complex, involving several departments, it is felt that a number of field observatories for regular monitoring of snow, weather, climate, water, suspended sediments, soil erosion and biodiversity need to be established so that uninterrupted field data is made available to help plan data-based strategies for the changing environment and to deal with effects of climatic change. This will enable us to coordinate with the International Geosphere Biosphere Programme (IGBP) and its Mountain Research Initiative (MRI) launched in July 2001 with the objectives to develop a strategy for detecting signals of global environmental change in mountain environments; to define the consequences of global environmental change for mountain regions as well as associated lowland systems; and to make proposals towards sustainable land, water and resource management at local to regional scales.

I am extremely happy that Dr. Jagdish Bahadur has collected and collated scientific and technical information on various topics connected with the gigantic natural system which is normally beyond a common comprehension. His long innings, working in the field of geology, hydrology, glaciology, agriculture and meteorology has been his strong points, enabling him to prepare the text of the present book on Indian Himalayas. I understand that it has taken more than six years of active work after his retirement from the services to plan and present the publication. I must congratulate him for his deep interest in Himalayas and the determined efforts to publish this book during this year being designated the International Mountain Year (IYM) by the United Nations. I hope that the book will encourage inter-disciplinary studies to conserve biodiversity, improve agricultural productivity and save the Himalayan region from further desertification.

(V.S. Ramamurthy)
Secretary, Department of Science and Technology
Technology Bhavan, New Delhi - 110016

FOREWORD

The present publication on Indian Himalayas, an integrated approach, emphasizing the need to study the atmosphere, geosphere & hydrosphere and biosphere along with mitigation of natural hazards for alleviation of poor socio-economic conditions of the mountains farming community, forms an informative and useful compendium for those interested in the development of the region. The author has taken advantage of his varied and long experiences and could endeavour to outline various and diverse sub-topics of relevance for the holistic study of the mountain environment with emphasis on sustainable mountain agriculture and eco-tourism. A large number of references, included in the book ,will further enhance the interest of future investigators.

In ICAR system, Vivekananda Parvatiya Krishi Anusandhan Sansthan (VPKAS), popularly known as Vivekananda Laboratory at Almora is charged with the mission to enhance productivity and ecological sustainability of hill agriculture through niche-based diversification and has contributed significantly to the development of the Himalayan region. At the national level, problems and prospects of natural resource management in Indian Himalayan region (covering about 16% of the geographical area and 4% of the human population of the country) are being coordinated by the Hill and Mountain Agro-system Directorate under National Agricultural Technology Project (NATP) at the Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Dehradun. The project is being implemented in an integrated inter-disciplinary, inter-institutional and farming system mode, encompassing critical areas, such as resource inventory and documentation, watershed hydrology, land-use planning, crop production, horticulture, livestock, fisheries and other small production systems of mushroom, rabbitary and bee-keepng. ICAR and its different research institutes including agricultural

universities are further cooperating with G.B. Pant Institute of Himalayan Environment and Development (GBPIHED) and the International Centre for Integrated Mountain Development (ICIMOD), Kathmandu for in-depth R&D studies on environmental problems to strengthen the local knowledge with suitable technological packages and delivery systems for sustainable development in harmony with local perception.

I recall listening to a lecture on Himalayas delivered in 1995 at IARI by Dr. Jagdish Bahadur and his spirited comments for further exploration of the high mountain region. He deserves our appreciation for the dedicated work to complete the present volume during this International Year of Mountains (IYM). to focus the attention of Indian Scientists and Planners and of all those interested in the Himalayan studies. The volume may be treated as an Indian contribution for the IYM.

PANJAB SINGH
Secretary (DARE) & Director General (ICAR)
Ministry of Agriculture
Krishi Bhavan, New Delhi

FOREWORD

Vigyan Prasar (VP) has been bringing out publications on a variety of topics related to Science and Technology popularization. Till date, VP has published series on Helath, Environmental Hotspots, Science Classics Reprints, Science Biographies, Natural History and monographs on Indian Scientific Heritage. This publication, incidentally, is a result of the intensive study of the Indian Himalayas by Dr. Jagdish Bahadur under the Utilization of Expertise of Retired Scientists' scheme of Department of Science & Technology.

Himalayas form the highest mountain chain in the world. It provides excellent opportunities and challenges for observation, monitoring and modelling of the natural resources and help solve problems of their management at local level.

I am happy to note that the publication "Indian Himalayas – an Integrated View" is being brought out during the International Year of Mountains (IYM). Dr. Jagdish Bahadur's long persuit and studies of Himalayan Mountain range have encouraged him to complete this Himalayan task. It is worth noting that the publication is being brought out at a time when India has been offered the leadership role by the International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, with which Dr. Bahadur has been associated since its establishment.

I do hope the labour of Dr. Bahadur would be rewarded through intense and meaningful investigations of the unique Himalayan environment and help alleviate the poverty of its inhabitants.

V B Kamble
Acting Director
Vigyan Prasar

PREFACE

From my childhood, I was fascinated by Himalayas – the storehouse of snow and ice and had a feeling that the floods in the Indo-Gangetic plains are related with the mountain system. This conviction was further strengthened when Government of India sponsored me to study the role of snow and ice during 1969-70 under a global postdoctoral fellowship from the Norwegian Agency for International Development, Oslo. During the fellowship period, I had opportunities to interact with global scientific community from various disciplines and made a proposal for initiating applied snow and ice investigation in India.

During my scientific service period of over four decades, I received training in geology and geophysics, hydrology, agriculture, environment, meteorology and science communication. The above experiences and my background in physics prompted me to explore and understand the role played by atmosphere, geosphere, hydrosphere and biosphere for the mega-biodiversity of the Himalayan region. Pursuant to this mission, a suggestion was made in 1991 to organize a land- atmospheric experimental campaign called 'Himalayan Experiment' (HIMEX) on the lines of Alpine Experiment (ALPEX) in Europe. This resulted in a three day brain-storming seminar at the Centre for Atmospheric Science (CAS) at IIT, Delhi in 1995 culminating in a volume on the Himalayan Environment. This volume consists of papers of various scientists for the advances made in the fields of snow cover studies, atmospheric studies, paleo-climatic and paleo-environmental studies, natural resource management and some concepts on Himalayan Experiment. Recommendations were made to improve data-bases for the region.

The present publication is the outcome to fulfill my long desire to compile, collate and document the scientific and technical information on various sub-topics connected with the Himalayan

Ecosystems. Widely varied and disparate information, touching several scientific disciplines has been presented to help launch further investigation of the Himalayan region which has stamped our lives and culture since the dawn of human civilization.

Depending on my limited capacity and limitation of time, an attempt is made to draw material from the explorations reported by various investigators with a hope that some curious minds will indulge in further explorations, unraveling the secrets of the great mountain system which has provided a place of pride to all Indians and its neighbours and global curiosity to others.

The book is meant for those who are keen to know the intricacies of the Himalayan environment and its role in sustaining a huge population of men and animals. An appeal has been made for a non-stop arduous effort towards its regeneration by all concerned based on holistic approach, integrating various disciplines and sectoral activities to eradicate the poverty from the region.

This book writing project was sponsored by Vigyan Prasar and funded under 'Utilization of Expertise of Retired Scientists (USERs) by the Department of Science & Technology,Government of India.

I shall feel gratified if the publication opens new horizons and vistas, giving some useful information to its readers during the International Year of Mountains (IYM).

(Jagdish Bahadur)

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I must express my grateful thanks to Dr. N.K. Sehgal, Founder Director, Vigyan Prasar who continued to constructively criticize to deepen my interest in Himalayas during my long association with him at Technology Bhavan. This book is the result of encouragment provided by him and the continued support from Dr. V.S. Ramamurthy, Secretary, Department of Science and Technology. Many seniors and colleague scientists and officers from various Government Departments, Research Institutes/Organizations and universities provided opportunities for intimate discussions and retrieval of information and relevant data for the present publication. The names of predominant among these collaborators and cooperators are included in the following list with their affiliations:

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PROLOGUE

One can talk of the Himalayas only in superlatives: highest peaks; the steepest escarpments; the most precipitious ravines; great crests crowned with perpetual snows towering above the most deeply scooped and verdant (green and fresh) valleys, with shining lakes and rushing streams; swift, cascading, falling, foaming rivers that cut the deepest gorges; the most numerous mountain glaciers which feed large river and lake systems; the highest-living species of plant and animal life found anywhere in the world, and the most highly diversified and sharply contrasted ecosystems which fall into ecological regions that cover practically a global range of climatic belts—from Tropical to Tundra — in a brief vertical span of six to eight kilometers. These are some of the characteristic features of their ranges, which make Himalayan Ecology unique (see Appendices for more descriptions of the mountain)

Uniqueness of Himalayan ecosystems is related to the intense coupling of the snow-land-ocean-atmospheric system. Himalayas are the house of eternal snow and ice. The ever-changing texture of the snow alters the radiation balance affecting ecosystems. Probably, the greatest importance of snow and ice is biological, just as snow provides insulation which permits plants and small animals to survive the severity of winter, similarly the cover of ice over a lake or a river prevents the loss of too great a quantity of heat, protecting the aquatic flora and fauna from cold injuries. The snow and ice from glaciers provide melt water for the sustenance of life. Both snow and ice also are reservoirs of micro-organisms which further nurture the agro-ecosystems of the mountain region and the associated plains.

The apex mountain is the youngest, tallest, most sensitive and extensive system on the Earth. The uplift of the Himalayas is largely responsible for the birth of *Indian monsoon*–the most spectacular and fascinating atmospheric phenomenaa as known to the whole

world. The rugged mountain topography affects air circulations on all scales of time and space (from planetary to micro waves). The seasonal variation of thermal and dynamical effects, over the massif, forms the modulating mechanism for seasonal adjustment of the planetary long waves of the North Hemispheric Air Circulations (NHAC). Due to lower mass of air at high altitudes, the changes of heat and moisture get magnified in the rarefied environment, when compared to those existing at the sea level, thereby increasing the sensitivity of the high mountain atmosphere. In general, the precipitation increases with altitude and it is maximum near the equilibrium line (the line on a glacier where a year' ablation balances a year' accumulation) on the glacier systems. Immature geological conditions over the Himalayas are responsible for its active geodynamic and geo-tectonic behaviour, resulting in frequent earthquakes. The mountain is still rising at differential rates at various locations. Due to enormous uplift, a substantial area of the mountain lies above the seasonal snow line, where the precipitation occurs throughout the year as snow, giving rise to vast snow and glacier fields which rival those in Polar Regions. Fluctuations of these huge snow and glacier fields, intense freeze-thaw cycle, slope instability and seismicity, create problems of frequent occurrence of natural disasters, such as, earthquakes, snow and ice avalanches, mudflows, landslides, flash floods, glacier-lake-outburst floods (GLOFs) adding a new dimension to the geodynamical behaviour of the earth surface.

Biogeographically, the Himalaya is a complex region. A sharp and distinct contrast characterizes the eastern region with warm and humid conditions and the western region with cold and arid environment. The agro-ecosystems in the Himalayan mountain region have been continuously evolving. The land is not so fertile and is prone to erosion. There are limited irrigation facilities and most of the region is under dry-land farming. Traditional farming is largely practised with crops maturing at different times of the year. Agriculture and animal husbandry are not practised in isolation but in combination as agri-silvi-cultural, agri-pastoral and agri-silvi-pastoral systems. The cultivars are individually poor in productivity but collectively the crop mixes are reasonably productive.

About 20 percent of the Himalayan region in the country is degraded. Urgent steps are needed to correct the situation based on scientific data so that the natural resources are conserved and their

productivity restored in mountains and the associated plains are saved from further desertification.

The rich biodiversity in plant and animal variety needs inventorisation and conservation. The sustainable development awaits a well coordinated and integrated multi-disciplinary approach. This becomes more important due to an increasing demand on Himalayan natural resources by an ever increasing population. The over-exploitation of the natural resources, increasing threats from pollution and introduction of exotic species are further affecting the rich biodiversity of the region.

To achieve a balance between food sufficiency and ecological stability, it is important to copy the nature by integrating different biota, such as, trees, shrubs, bushes, high-value crops and/or animal husbandry. Unfortunately agriculture, forestry, and animal husbandry have grown independently due to separate departmental development prograammes and there is little appreciation of the fact that these form land-use activities and need integration. The traditional systems have been evolved by trial and error by the farming community. These systems need to be preserved and improved by adding scientific inputs for tree-crop-animal husbandry in the poly-cultural systems for sustainable development of the mountain agriculture.

Chapter 1

INTRODUCTION

With a brief prologue on Himalaya, the publication contains eight chapters entitled (i) Introduction, (ii) Indian Himalayas and it's Agro-ecosystems, (iii) Atmospheric Aspects, (iv) Geo-spheric & Hydrologic Aspects, (v) Bio-spheric Aspects (vi) Natural Disasters and Mitigation, (vii) Socio-Economic Aspects, (viii) Resource Monitoring, Institutional Infrastructure and Policy Issues, illustrated with diagrams, tables and photographs accompanied by an epilogue.

The prologue, introduces some superlative and fascinating features of the Himalayas, the colossus among the great mountains.. The first chapter deals with the contents of the book with salient points made in different chapters. The second chapter deals with the spread of Indian Himalayan Region (IHR) with predominant mountain peaks and passes. The mountain and hills cover 14 states in two geographical regions i.e.western and eastern regions, covering 90 districts. The ecosystems diversity in different agro-ecological zones is briefly described with data on demographic structure and major landuse patterns. Higher decadal growth of human population (1981-91) and the non-working population may be mainly responsible for environmental degradation of the region. It introduces basics of agro-ecosystems with some basic functions. Various elements like the sun, a-biotic substances, primary producers, consumers and decomposers are discussed in relation to energy flow (biomass production) and the food web. The cycling of chemical elements and compounds in living things are briefly dealt with, highlighting the importance of phosphorus. The slow and subtle changes in ecosystems are pointed out in relation to the laws of balance in nature. Attention is drawn to the origin and the evolution of high altitude organisms, being the integral parts of the high altitude ecosystem but not the *man*, even when he is gifted with unique capacity to shape his own environment. Uniqueness of the Himalayan mountain system is related to the intense

coupling of snow with the land, the ocean, and the atmosphere. The dynamics of the subsystems is related to huge snow and glacier fields, the intense freeze-thaw cycle, the slope instability and the seismicity, resulting in frequent occurrence of natural hazards like earthquakes, snow and ice avalanches, mudflows, landslides, flash floods, glacier-lake outburst floods (GLOFs). The changing development dilemma in the region is discussed in relation to fragility of the environment and conservation of natural resources for long- term sustainable development of agriculture and eco-tourism in the region.

The third chapter deals with the atmospheric aspects including barrier effects, geographical factors (altitude, latitudinal and longitudinal effects), microclimates, thermal effects, dynamical effects, seasonal aspects, monsoons, hydrometeors and hydrometeorology, paleo-climatological investigations, climate-change investigations, weather forecasting and agro-meteorology. With a brief introduction of the atmosphere and its structure, various spatial and temporal scales (micro, local and regional) in mountain weather and climate are tabulated along with the basic mountain climate as influenced by altitude, continentality, latitude and topography and the atmospheric motions from the microwaves to the planetary waves. The barrier effects are introduced along with the role of Himalayan ranges in limiting northward movement of moist summer monsoon air and the southward movement of cold dry Arctic winds. Various microclimates in the large altitudinal ranges in the mountains are tropical (300-900 m), warm temperate (900-1800 m), cool temperate (1800-2400 m), cold (2400-3000 m), Alpine (3000-4800 m) and perpetually frozen (above 4800 m). Altitude dependent distribution of temperature for warmest months for Himalaya and Karakoram are tabulated with the snow line and tree line for various mountain ranges. Four principal seasons e.g. winter (Dec-Feb), Hot (Mar-May), Summer (Jun-Sept) and transition (Oct-Nov) exist in the Himalayan region. The role of Tibetan plateau in controlling the seasonal circulations has been outlined. Monsoon has been described as a system of alternating winds from over Arabian sea and the Indian Ocean. Various phases of the monsoon in terms of rainfall distribution are outlined. Precipitation distribution with regard to orographic increase from western to eastern mountain region is given along with the increase in different altitude ranges for summer and winter months from available observed precipitation data of Indian stations. Common

hydrometeors are defined, outlining the importance of hydro-meteorology for reconstruction and development of the natural environment. Attempts to cover deficiencies in hydro-meteorological observation networks are indicated. Paleo-climatological investigations based on natural archives are listed along with recent efforts to reconstruct the paleo-environments over the Himalayan-Tibetan Plateau region. The vegetational succession and climatic oscillations, impressed chiefly from the study of Karewa deposits in Kashmir cover 3.8 m yr.; in Himachal Pradesh 8000 yrs; in Garhwal Himalaya 6000 yrs; more than 40,000 yrs in Kumaon Himalayas as well as the Kathmandu valley (Nepal); 20,000 yrs in Darjeeling and 2,500 yrs in Sikkim. In joint American and Chinese studies, ice cores from two ice caps in Tibet (NW Guliya at 6200 m, precipitation 180 mm/yr; NE-Dunde at 5325 m, precipitation 1400 mm/yr) were used to reconstruct the temperature histories which reveal some centennial – scale similarities but quite different for higher frequency variability over the last millennium. The most important finding was the marked warming for few decades in NE region but the warming signal over the NW region was observed since 1985 only. The role of monsoons in Himalayan glaciation is observed to correlate with 23,000, 41,000 and 100,000 year orbital cycles. The climate change investigations due to anthropogenic forcings by increasing atmospheric concentration of carbon dioxide and/or other greenhouse gases are briefly reviewed with some of the implications for the Indian sub-continent. Studies on climatic scenario, utilizing seven recent climatic models up to 2100 AD, show that for Himachal Pradesh, the projected temperature and precipitation changes are annual temperature rise about 3° C, winter temperature rise about 3° C, spring temperature rise about 7° C, summer temperature rise about 4° C with a wide range of uncertainty. The annual precipitation change of +20%; winter change +30% to –15%; spring change +30% to –12% and autumn change +15% to –15%. Weather forecasting on various time scales e.g. very short range (now casting), short range, medium range and long range are introduced along with numerical weather prediction (NWP) which are affected by systemic deficiencies and there is a need for better understanding of physical processes,affecting the Himalayan region. The importance of agro-meteorology for enhancing agricultural production in the mountain region is emphasized due to frequent changes in weather elements. Agrometeorological Advisory

Services rendered by NCMRWF in the mountain region are briefly included. Good farm level management models need improved understanding of land-atmospheric processes by performing new experiments and improving the observational networks

In chapter 4, various geospheric and hydrologic aspects have been dealt with.. These include orogeny, geology and geomorphology, geotectonics and geodynamics, mineral wealth, geothermal energy, glaciations (snow cover, glacial cover and glacier inventory), soil formations, soil erosion and sediment transport, natural lake systems, perennial river systems, (Indus, Ganga & Brahmaputra), man-made water reservoirs and springs , surface flow and groundwater. The uplift of the Himalaya took place in three main phases i.e. Early Miocene (70-21 m yr B.P.), Late Miocene (11-7 m yr.B.P.) and Quaternary (1.6 m yrB.P. to the present). These mountains are generally divided in three longitudinal zones i.e. the Great Himalayan Range (*Himadri*) with average elevation of 6100 m; the Lesser Himalayan Ranges (*Himachal*) with average height of 2600-4600 m and the Outer Himalayan Range (*Siwalik*) with an average elevations from 1000 to 1300 m. Himalayan geology and geo-morphology are very complex due to intricate orogeny, encompassing a complex set of changes in rocks both at depth (metamorphism, magnetism and structural deformation) and on the surface (uplift and degradation.). The most recent geological map has been included with major geomorphic features. Geotectonics due to crustal disturbances and the role played by Main Central Thrust (MCT) and Main Boundary Thrust (MBT) for mountain building are outlined. Geodynamics of the region is controlled by the movement of Indian mass northwards resulting in earthquakes and landslides. Repeated geodetic and geophysical surveys show that the isostatic equilibrium does not prevail in the Great Himalayan ranges and the upliftment of the mountain continues at a rate of 1.5 to 2 mm/yr. The crustal movement is not uniform in horizontal and vertical planes all over the Himalayan region. Diverse mineral wealth of the Himalayan region within the Indian territory, as presently assessed, is included. Geothermal energy is wide spread all along the fault zones and needs proper utilization. Glaciations are considered to include the snow cover, the glacier cover and the glacier inventory. It is pointed out that the Himalayan glacier fluctuations are controlled by variations in both the South Asian monsoon and the mid-latitude westerlies. Glaciers were less extensive

in the Himalayas during global glacial maxima due to increased continentality of the climate of high Asia. Monitoring of the Himalayan snow is considered important for weather forecasting on various time scales. In the context of air circulations, it has been observed that the maximum snow cover results in maximum zonality (E-W) while the minimum snow cover supports maximum meridionality (N-S) and variable snow cover introduces horizontal temperature gradient resulting in cyclogenesis and blocking, thereby modifying the weather. Himalayan glaciers differ from other high latitude glaciers in having dense debris cover in ablation zone. There is substantial dust, biomass and bacterial spread on them. Summer temperatures over the glacier are higher on southern slopes. It is usually above 10° C and could touch upto 25-30°C ,resulting in generation of abundant meltwater. It is estimated that the glacier area over the Himalayan region including Tibet ranges from 94,554 km^2 to 97,020 km^2. It is claimed that 49.8% of these glaciers lie in Chinese territory. Recent glacier inventories prepared by the International Centre for Integrated Mountain Development (ICIMOD) show that about 107 km^2 lie in Bhutan and 76 km^2 in Nepal, while the glacier area within the Indian territory is ~ 37,959 km^2 totaling to 38,142 km^2 while Chinese estimates show that the glacier area of 47,441 km^2 lie outside China. The author estimates that a glacier area of about 50,000 km^2 drains into Indian land mass as a substantial drainage of the upper catchment area of Indian Himalayan river basins lies outside the national territory. There is an urgent need for a serious study to map the area and make proper assessment of water resources from the glaciated region. This will enable the planners and water resources managers to take appropriate ameliorative measures,well in advance, against the perennial problems of floods and droughts, affecting the nation.The great variability in soil formations and soil cover need special care against soil erosion for the upkeep of soil fertility. The high content of suspended sediments and its seasonal variation in various tributaries of Himalayan rivers needs specific bio-engineering methods for its reduction and control. Both saline and freshwater lakes abound over the region and each lake system needs scientific studies for its proper management. It may be noted that the specific water discharge i.e. water yield per unit area in the high mountain catchment for arid Indus is about three times the average for the whole Indus; this figure is about twice for the average

specific discharge for Ganga and it is only 10% higher for humid Brahmaputra. Probably, international water treaties and agreements are needed for efficient water resource management for the Indian Himalayan rivers. Much more effort and investments are needed to create small and big reservoirs at the surface and the underground for overall regeneration of the mountains.

The fifth chapter deals with bio-spheric aspects; the west Himalayan province supports a cold and drought resistant vegetation dominated by conifers (chirpine, blue pine, deodar, fir and spruce), legumes grasses and composites while the eastern flanks harbour a wet humid sub-tropical vegetation rich in mongolias, oaks, laurels, terminalias, rhodendrons, epiphytes, orchids and ferns. The chapter briefly outlines the pastures and grasslands, forests, food crops, horticultural crops, medicinal plants, livestocks, fisheries micro-organisms and conservation measures through biosphere reserves in the Indian Himalayas.

Micro-environmental and agroecological diversity of the Himalayas have produced a spectrum of rangeland ecologies spreading from 300 m to 4500 m. Over- exploitation of natural pastures and grasslands awaits a long-term coordinated scientific intervention for their regeneration. The importance of Himalayan forest cover cannot be underestimated, because it is linked with long term environmental security of the region and the agrarian economy of the hill region which is heavily dependent on forest for energy supply, fodder, non-timber products and livestock rearing. Improved management practices of forestry and agro-forestry would go a long way towards integrating forests with agriculture. Trees, shrubs and other vegetation help control temperature extremes by moderating the desiccating effects of solar radiation and also increase relative humidity. Forests build up litters, which is of great importance for the control of sediment and water regime and regulated flow of water in rivers. Mixed cropping is very popular in the Himalayan region. Cereal and millets are generally sown with legumes. Major mixed crop production associations are wheat/rice and rice/maize/millets. Variations in these occur at different elevation zones under rain-fed and irrigated conditions. Barley/wheat/pulses zone in higher altitude breaks up into barley/wheat/pseudo cereals (buck wheat, amaranthas)/ pulses. A very interesting combination in the eastern Himalayan region/north eastern region is of tea/horticultural crops/rice.

Altitudinal limits of different crops have been incorporated. Horticulture, as an economic activity is of great importance to Himalayan region. Due to climates ranging from subtropical to temperate, a wide range of fruits (citrus, banana, mango, apple, pineapple, walnut, plum, peach, cherries etc.; vegetables (potato, pea, capsicum, carrot, cabbage, cauliflower etc.); spices (garlic, ginger, chillies, cardamom, black pepper etc.) and flowers (orchids, gladiolus, marigold, chrystanthemum etc.) are grown in the region. Major constraints are low productivity; low use and availability of good quality inputs like seeds/planting materials, fertilizer, water, labour etc.; acute absence of technological interventions; weak research and extension support, depletion of natural resources due to deforestation and urbanization, remoteness of areas and inaccessibility of major markets; absence of basic infrastructure and inadequate institutional support. Despite these shortcomings the horticultural crops offer greater opportunities for higher and sustainable development of the region. Himalayan herbs including medicinal and aromatic plants were documented in Vedas (4500 to 600 BC). Ayurveda provided details for therapeutic use of as many as 290 herbal drugs. India occupies the top most position in the use of herbal drugs utilizing nearly 540 plant species in different formulations. Presently, about 1000 single drugs and 8000 compound formulations of Ayurveda are in vogue. Herbal drugs have attracted a global attention for medication. It is strongly felt that agro-technologies and propagation protocols need to be developed for sustainable utilization, conservation and management of threatened plant species. Livestock has become an integral part of Himalayan production system. Major constraints for enhanced animal productivity are health care, mass multiplication of desirable breeds, improved nutrition and control of animal density. Grazing pressure has already reached several fold the carrying capacity of pasture lands and needs to be saved from further desertification. Among 258 fish species identified from Indian uplands, 203 are reported from Himalayas as against 91 from the Deccan plateau. A lot of depletion in species number and their yield in both still and flowing waters have been observed. Fish conservation strategies has to adopt strict enforcement of fishery regulations, prevent destructive and illegal fishing, protect breeding grounds, catchment improvement for water quality, conservation of fish seeds and mass scale seed production along with phased and regular

ranching programme of endangered species. Micro-organisms are known to play a crucial role in various processes related to soil fertility and plant production. An immense diversity exists among micro-organisms. Microbial diversity encompasses a spectrum of microscopic organisms including bacteria, fungi, actinomycetes, algae, and protozoa. It is estimated that 50% of all living population on earth is microbial. Culture collection all over the world including India have been playing a major role in preservation of the micro-lives. A general summary on the status of biodiversity has been included to highlight the importance of world's richest ecosystems of the Himalayan region. Available information on diversity of plants; the wild relatives of crop plants; reptile amphibian and fish fauna has been included and it has been pointed out that the mega-biodiversity of the region presents a truly Himalayan task for inventorization, conservation and its sustainable use. Latest information about conservation measures and biosphere reserves in the Indian Himalayan region are given with the identification of gaps for scientific management of these bio-reserves so that environmentally compatible packages of practices, suiting the local cultural heritages are evolved for sustainable development.

The sixth chapter deals with natural disasters and mitigation. Natural Hazards in these mountains are associated with immature geology, extreme weather and climatic conditions due to high temperature oscillations at different times. High seismicity, climatic extremes including cloudbursts, snow and ice avalanches, debris flows (including mudflows and debris landslides), outbursts from moraine-dammed lakes, glacier lake outburst floods (GLOFs), forest fires are covered with some details along with the mitigation and monitoring of these natural hazards.

In the seventh chapter, socio-economic aspects e.g. degradation of common property resources (CPRs), food insecurity, migration of male working population, poor technical and management skill, structural and attitudinal conditions of social set-up, local institutions and women organizations and empowerment are briefly incorporated.

The eighth chapter deals with resource monitoring, institutional infrastructure and policy issues. Natural resources are under great stress due to geological instability interacting with complex problems, including population pressure, deforestation, landslides, erosion, water scarcity, out-migration and poverty manifest fragility to the resource

rich Himalayan ecosystems. The region still enjoys a monopoly in the production of virus-free potato tubers, temperate fruits like apples and several other high value cultivated crops as well as wild crops which provide scope for designing alternatives or complements to traditional agriculture as an instrument for development of the region. Lack of representative observational data for problems like denudation, siltation, hydrological imbalances suffer from drawbacks including generalized surveys and tremendous extrapolation for site-specific observations to large heterogeneous areas. Data on climate, soils, geological features, human settlements, needs to be integrated with biological data to gain insight into the distribution of biodiversity in the context of physical parameters and human population. The resource monitoring and research has to assess the current status and rate of loss of Himalayan biodiversity along with the biomass requirement for human needs. To reduce the anthropogenic threats, changes in government policies and education of the public of the value of biodiversity are needed. With the help of Geographical Information System (GIS), it is now possible to integrate biophysical and socio-economic data as it is now recognized that GIS has become a powerful and dynamic tool for decision-makers in preparing alternative policies and strategies for sustainable and integrated mountain development. There is also a need for anticipatory research for renewable energy sources, consumer preferences, packaging and marketing, adopting biotechnology, computer simulation etc. for providing the guidance to resource developers.

Institutional and organizational infrastructure established since eighteenth century are given with the names of Central/State Universities, ICAR and other major Research and Development Institutions and Organizations. There is need to establish a back-up consortium of government departments, technical institutions/ universities to provide guidance and a monitoring oversight to the programme of ecological security in the region. As the policy has to be modified and fine tuned from time to time due to interplay of technology with the needs of development, we have to evolve integrated approaches after due consultations from various disciplines and the government departments and agencies to stimulate peoples participation. The basic philosophy of new institutions,besides a clarity of focus, should be to establish transparency, equity, active participation and conflict resolution.

Presently, Himalayas are suffering from serious ecological repercussions, e.g. population increase of diverse cultures, reduction in forest cover resulting in severe soil erosion, extensive runoff, and land degradation. Sub-marginal lands are brought under cultivation resulting in poor soil and water conservation and silting up of drainage channels; shifting cultivation in North-East, dislodging staggering volume of soils; indiscriminate hunting threatening its fauna and unplanned mass tourism creating further increased ecological degradation. The region has become a battle-ground between conservationists and commercial interests. There is a general agreement that the problems of the region can neither be solved by high-tech approach nor by doom-sayer's dreams that there is no longer any hope for the environment. Only a mixture of deep concern and cautious optimism is needed. Avarice and indifference should not be allowed to destroy the natural heritage of tremendous importance for one and all. As the Himalayan mountain system produced the stimulus for human origin as a biological entity, the multiple challenges to the adaptive processes posed by the contemporary problems related to the region, should stimulate humanistic impulses to be expressed in the most prudent and creative manner. Our hominid ancestors started a journey at the foothills of the Himalayas, let us try to reach the peak of humanist self-realization through mutual cooperation and nonstop arduous efforts for its regeneration to attend to the welfare of resident population and the removal of poverty from the mountain region.

Chapter 2

INDIAN HIMALAYAS AND IT'S AGRO-ECOSYSTEMS

2.1 INDIAN HIMALAYAN REGION

The Indian Himalayan Region (IHR) is spread between 21°57′ – 37°5′ N latitudes and 72°40′ - 97°25′ E longitudes covering an area of 53.7 million ha which is 16.4 percent of the total geographical area of the country (Samra, J.S. et al 1999). In the high altitude region there are about a hundred peaks above 6000 m which represent glacial and periglacial features. The prominent mountain peaks and passes are given (Table 2.1)

TABLE 2.1

Altitudes of Prominent Himalayan Mountain Peaks and Passes in India*

Altitudes in m (a.s.1)

Mountain Region	*Peaks*	*Passes*
Jammu and Kashmir	Baltit, 7785	Babuser, 4173
	Basherbrum, 8000	Banihal, 2832
	Broad peak, 8056	Bundil Pir, 4200
	Chalung, 6546	Burji La, 4816
	Chumar, 6410	Burzil, 4199
	Disteghil Sar, 7885	Changla, 5599
	Harmosh, 7397	Chilung La, 4401
	Kampire Dior, 7143	Deosai, 3765
	Kanjut Sar, 7760	Digar La, 5400
	Karakoram, 8611	Karakoram, 5575
	Nangaparbat, 8126	Khardong La, 5602
	Nunkum, 7135	Kongkha, 5200
	Rakaposhi, 7788	Kyung Zing La, 6410
	Saltoro Kangri, 7742	Lachulung La, 5500
	Taltakuti, 7742	Marsemik, 6050
	Trivor, 7788	Parpik, 5500

(Contd.)

(Table 2.1 Contd.)

Mountain Region	*Peaks*	*Passes*
		Penzella, 4220
		Pir Panjal, 3494
		Poat La, 5716
		Polokondla, 5200
		Sur, 5700
		Tanglang La, 5700
		Tsaka La, 4724
		Zojila, 3529
Himachal Pradesh		
	Bara Shingri, 5880	Baralacha, 4512
	Barakanda, 5877	Bhaba, 4890
	Chocho Lang, 6400	Chancil, 4220
	Gyagar, 6400	Cheni, 4423
	Gyah, 6794	Chharpar, 4980
	Jorkanden, 6473	Chobia, 4966
	Kailash, 5656	Drati, 4694
	Kinner Kailash, 6473	Ghasutri, 4588
	Kulu Pamori, 6481	Jundel, 3658
	Leo-Pargial, 6791	Kaban La, 4905
	Lhakhang, 6250	Kalicho, 4803
	Mani-rang, 6554	Kinner, 5500
	Menthosa, 6444	Kugti, 5040
	Mulkila, 6517	Kunzam La, 4551
	Papsura, 6451	Manessar, 3949
	Parbati, 6633	Manirang, 5335
	Shigri-Parbat, 6578	Parang La
	Shikar Beh, 6200	Punjung La, 2744
	Snow dome, 5947	Rangcha, 4400
	Tent peak, 6133	Rohtang, 3915
	White soil, 6455	Sach, 4390
		Shibaling, 3980
		Shipki La
		SisbangSuru, 4300
		Syanna LaTakling La, 5275
		Tempola, 4930
		Yangzi Diwan
Garhwal and Kumaun		
	Badrinath, 7138	Darma, 5100
	Bandarpunch, 6315	Lipu Lekh, 5200
	Bhatgirath I, 6856	Mana, 5600
	Bhagirath II, 6454	Niti, 5068
	Bhagirath III, 6512	Ralam, 5500

(Contd.)

(Table 2.1 Contd.)

Mountain Region	*Peaks*	*Passes*
	Bhrigupanth, 6772	Trail, 5500
	Chaukhamba, 7138	
	Darpata, 6482	
	Dunagiri, 7066	
	Gangotri, 6614	
	Gauri, 6590	
	Hathi, 6727	
	Jaonli, 6632	
	Kedarnath, 6940	
	Kamet, 7756	
	Maiktoli, 6650	
	Mana Parvat, 6795	
	Meru, 6660	
	Nanda Devi, 7817	
	Nandakana, 6300	
	Nandakot, 6861	
	Nar, 5831	
	Narayan, 5965	
	Nilkanth, 6596	
	Panchhulhi, 6910	
	Pithwara, 6904	
	Satopanth, 7075	
	Sivling, 6543	
	Srikanta, 6132	
	Sumeru, 6350	
	Surgnalin, 6252	
	Trisul, 7120	
	Vasuki Parvat, 6792	
Eastern Himalaya		
	Chomo Lhari, 7314	Andra La
	Chomo Yomo, 6828	Bum La, 4331
	Jonsong, 7065	Dom La
	Kabru, 7338	Donkya La, 6000
	Kangchenjunga, 8598	Jelap La, 4000
	Kangto, 7089	Nathu La, 4000
	Kulha Kangri, 7541	Thag La
	Lama Anden, 5876	Tulung La
	Narsing, 5831	
	Pandim, 6709	
	Pauhunri, 7128	
	Siniolchu, 6815	
	Talung, 7351	

* Source : Negi, S.S. (1998)

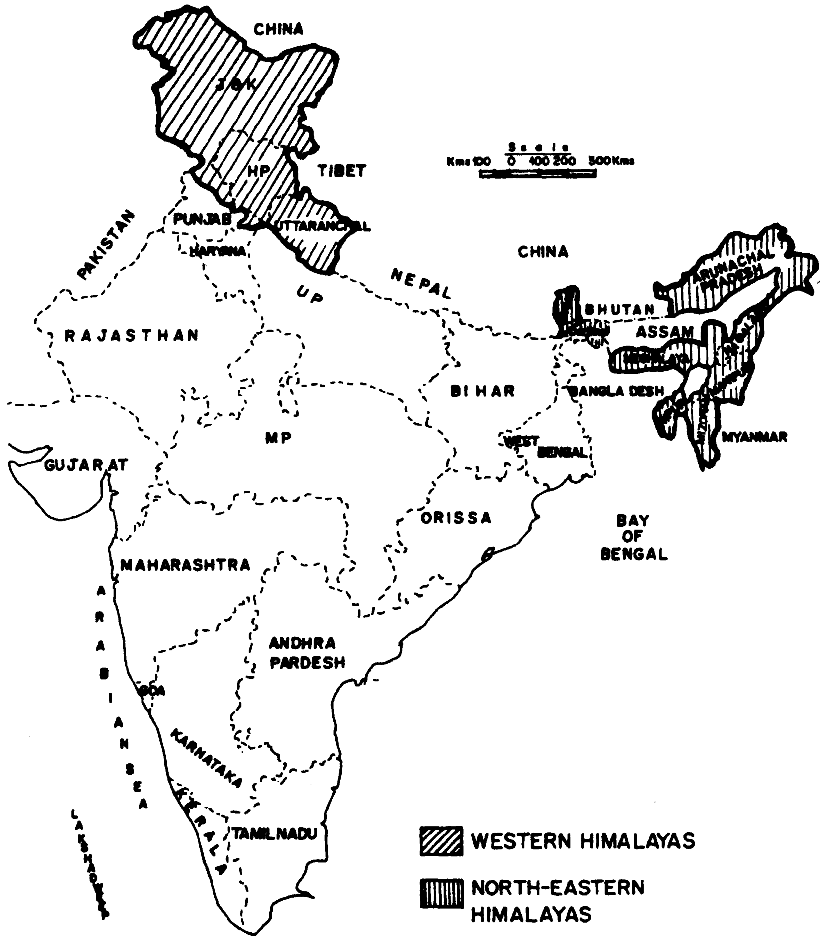

Fig. 2.1.1 Area representing hills and mountains in Western and North-Eastern Himalayan States of India.

In the country, the mountains and hills cover 14 states and 90 districts in two distinct geographical regions viz. Western and Eastern region (Fig. 2.1.1). The western ranges extend from Jammu and Kashmir, Himachal Pradesh, Siwaliks of Punjab, Haryana and Uttaranchal (Fig. 2.1.2), while the eastern Himalayas cover north-eastern hill states of Arunachal Pradesh, Manipur, Meghalaya, Mizoram Nagaland, Sikkim, Tripura and parts of Assam and West Bengal (Fig. 2.1.3)

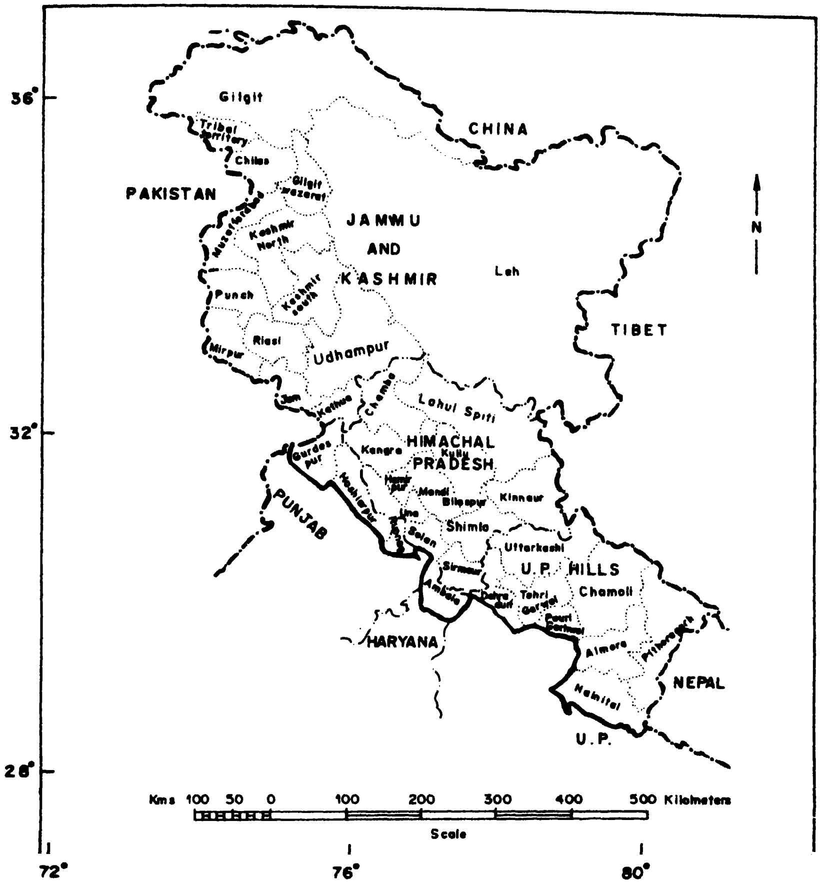

Fig. 2.1.2 Area representing hill and mountain districts in the Indian Western Himalayan Region.

TABLE 2.2

Area Representing Hill and Mountain Districts in Indian Himalayan Region*

States	*Districts covered*	*Geographical area in ha*
North-eastern Himalayas (49)		
1. Arunachal Pradesh	West Kameng, Tawang, East Kameng, Lower Subansiri, Upper Subansiri, West Siang, East Siang, Dibang Valley, Lohit, Changlang, Upper Siang, Tirap and Papumpare (13)	8.37

(Contd.)

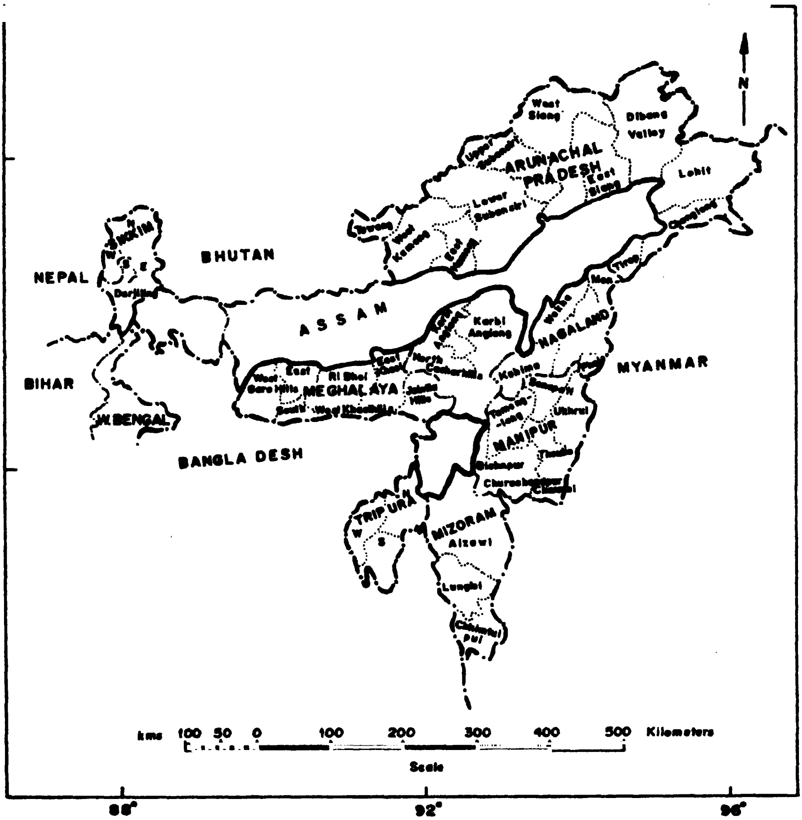

Fig. 2.1.3 Area representing hill and mountain districts in the Indian Eastern Himalayan Region

(Table 2.2 Contd.)

	States	*Districts covered*	*Geographical area in ha*
2.	Manipur	Senapati, Tamenglong, Churachandpur, Chandel, Thoubal, Bishnupur, Imphal and Ukhrul (8)	2.23
3.	Meghalaya	Jaintia Hills, East Khasi Hills, West Khasi Hills, East Garo Hills, West Garo Hills, Ri-Bhoi and South GaroHills (7)	2.24
4.	Mizoram	Aizwal, Lunglei and Chhimtuipui (3)	2.11
5.	Nagaland	Kohima, Phek, Zunheboto, Wokha, Mokokehung, Tuensang and Mon (7)	1.66

(Contd.)

(Table 2.2 Contd.)

	States	*Districts covered*	*Geographical area in ha*
6.	Sikkim	East Sikkim, North Sikkim, South Sikkim, and West Sikkim (4)	0.71
7.	Tripura	West Tripura, North Tripura, South Tripura and Dhalai (4)	1.05
8.	West Bengal	Darjeeling (1)	0.32
9.	Assam	Karbi Anglong and North Cachar Hill (2)	1.53
Western Himalayas (41)			
10.	Himachal Pradesh	Una, Hamirpur, Bilaspur, Kangra, Chamba, Solan, Mandi, Kullu, Shimla, Sirmaur, Kinnaur, and Lahaul and Spiti (12)	5.57
11.	Jammu & Kashmir	Jammu, Udhampur, Kathua, Doda, Punch, Rajouri, Srinagar, Budgam, Anantnag, Pulwama, Baramula, Kupwara, Leh and Kargil (14)	22.22
12.	Uttaranchal	Dehradun, Tehri Garhwal, Almora, Pithoragarh, Nainital, Uttarkashi, Chamoli and Pauri Garhwal (8)	5.11
13.	Punjab	Parts of the districts of Gurdaspur, Hoshiarpur, Nawan Shahar and Rupnagar (4)	0.38
14.	Haryana	Parts of the districts of Ambala, Panchkula and Yamunanagar (3)	0.21

*Source: Samra, J.S. et al (1999)

Himalayas are known for the diversity of its ecosystems. Some important features associated with the ecosystem diversity in IHR are given in Table 2.3

TABLE 2.3

Some important features of ecosystem diversity in the Indian Himalayas*

Attributes	*North-eastern Himalayas*	*Western Himalayas*
Geographical area (m ha)	20.22	33.49
Climate	Extremely wet and warm	Dry and cold
Latitude	21°5′ -29°3′ N	29°31′ - 36°58′ N

(Contd.)

(Table 2.3)Contd.

Attributes	*North-eastern Himalayas*	*Western Himalayas*
Longitude	85°5′ - 97°5′ E	73°26′ - 83°30′ E
Elevation (m,asl)	200 – 8598	400 - 8611
Highest mountain peak (m)	Kanchenjunga (8598)	K-2 (8611)
Annual rainfall (mm)	2800 – 12000	350-3000
Mean temperature (°C)	8-22	8-22
Physiography	Gentle slopes	Steep slopes
Soils	Deep to shallow and acidic to neutral in reaction	Shallow and neutral to acidic in reaction
Vegetation	Tropical forest (Rhododendron spp., laurels, alder, birch and willows)	Cold loving and drought resistant (oak, blue pine, deodar, fir, spruce, sal, junipers and Buglyals)
Farming system	Shifting cultivation and settled	Settled
Livestock	Pig, mithun, yak, cow and poultry	Cow, sheep, goat, buffalo and yak
Dominant land ownership	Commuity and private	Government and private (mainly forest)
Ethnicity (dominant religions)	Christian, Muslim and Buddhist	Hindu, Muslim and Buddhist
Major tribes	*Bhutia, Lepchas,Chakma, Naga* and *Mizo*, with a large number of sub-tribes	*Bhotia, Gaddis, Gujjar* (nomadic), *Rajees, Tharus, Buxas* and *Jaunsarees*
Property inheritance system	Matriarchal	Patriarchal
Mariage system	Polygamy in some tribes	Polyandry in some tribes
Minerals	Petroleum and natural gas, coal, silmanite, limestone and glass	Gypsum, limestone, dolomite sand and pyrite

*Source : Samra, J.S. et al (1999)

Out of 21 agro-ecological regions of the country, four regions are covered exclusively and one partly in the hill and mountain agroecosystem. Their characteristics showing the variations in climate, crop growing priod, soils, dominant and natural vegetation are listed (Table 2.4)

TABLE 2.4

Major agro-ecological zones of the Indian Himalayas*

Characteristics	*North Western Himalayas*	*Northern Plain*	*Western Himalayas*	*Eastern Himalayas*	*North-eastern Hills*
Name of district	Ladakh and Gilgit of J&K, parts of Lahaul and Spiti region of H.P.	Shiwalik region of H.P., Punjab and Haryana, *tarai* of Uttaranchal and some parts of U.P. plains and Bihar	Rest of J&K, H.P.	Darjeeling district of West Bengal northern parts of Assam and major part of Arunachal Pradesh and Sikkim	Nagaland, Meghalaya Manipur, Mizoram and Tripura
Geographical area (m ha)	15.6	1.7	17.7	8.0	10.7
Mean annual temperature (°C)	8	22	15-22	8-15	8-22
Annual rainfall (mm)	<150	1000-1200	1600-2000	>2000	1600-2600
Climate	Cold arid	Hot sub-humid	Warm sub-humid and humid	Warm perhumid	Warm perhumid
Summer	Mild	Warm	Mild	Mild	Warm

(Contd.)

(Table 2.4 Contd.)

Characteristics	*North Western Himalayas*	*Northern Plain*	*Western Himalayas*	*Eastern Himalayas*	*North-eastern Hills*
Winter	Severe	Cool	Cool to cold	Moderate to severe cold	Cold
Crop growing period (days)	90	150-180	180-210	>270	<210
Soils	Skeletal and Calcarious	Deep loamy and high organic matter	Shallow to deep loamy, forest and podzolic brown soil, with medium to high organic matter	Shallow and medium brown red hill soil, with low organic matter	Shallow and medium loamy red yellow lateritic soil
Soil reaction	Alkaline	Neutral	Neutral to acidic	Acidic	Acidic
Dominant natural vegetation	Sparse vegetation such as willow	Tropical dry deciduous forest	Moist temperate tropical pine and sub-alpine forest	Sub-tropical pine and temperate evergreen forest	Wet ever green and tropical moist deciduous forest

*Source Sehgal, J.L. et al (1990)

The mountain houses a population of 33.8 million people which is about 4 per cent of total population of the country. Agriculture is the primary sector of the economy contributing 45 per cent of total income as compared to 42 per cent for the whole country. About 60 per cent of the work-force is engaged in agricultural activities as against about 30 per cent in the non-Himalayan states.

TABLE 2.5

Demographic structure in the Indian Himalayas*

State	*Human population (,000)*	*Population density (per 1000 ha)*	*Total workers (,000)*	*Agri-cultural workers (,000)*	*Per capita arable land (ha)*
North-eastern Region					
Arunachal Pradesh	864	103	400	256	0.17
Manipur	858	384	775	484	0.16
Meghalaya	1,774	791	785	486	0.11
Mizoram	690	313	337	188	0.09
Nagaland	121	73	516	379	1.68
Sikkim	406	572	168	108	0.23
Tripura	2,757	2,628	858	494	0.10
Assam*	3,657	2,387	1,280	934	0.74
West Bengal*	999	3,171	572	418	0.09
Total	12,126	597[1.4]	5,691[1.8]	3,747[3.8]	0.32
Western Himalayas					
Himachal Pradesh	5,170	929	2,214	1,184	0.11
J & Kashmir	7,718	347	-	-	0.10
Uttaranchal	5,923	1,158	3,109	1,792	0.11
Punjab*	898	2,354	341	119	0.07
Haryana*	1,938	9,099	678	278	0.03
Total	21,647	646[2.6]	6,341[2.0]	3,373[3.4]	0.10
Total Himalayas	33,773	627[4.0]	12,032[3.8]	7,120[7.2]	0.17
Non-Himalayan region	8,12,530	2,955[96.2]	3,02,099[31.0]	93,512	0.17
All India	8,46,303	2,574[100]	3,14,131[100]	1,00,632[100]	0.17

*Source: GoI (1991)Include only those districts which are covered under hill and mountain agro-system.figures in brackets are percent of all India

The mountain regions are thinly populated having a population density of 627 per 100 ha as against 2,955 for the non-Himalayan region and 2,574 for India as a whole. Despite this, the actual pressure on the agricultural land is much higher as the net cultivated area is only about .12% of the reporting area compared to 50% in the non-Himalayan region and 47% in the whole country (Table 2.6).

TABLE 2.6

Major Landuse Pattern in the Indian Himalayas (thousand ha)*

State	Total geographical area	Reporting area	Forests	Permanent pastures & grazing lands	Net area sown	Others
North-eastern Region						
Arunachal Pradesh	8,374	5,495	5,154	-	185	156
Manipur	2,233	2,211	602	-	140	1,469
Meghalaya	2,243	2,241	937	-	206	1,098
Mizoram	2,108	2,088	1,598	-	109	381
Nagaland	1,658	1,546	863	-	211	472
Sikkim	710	710	257	69	95	289
Tripura	1,049	1,049	606	-	277	166
Assam*	1,532	1,521	548	21	350	602
W. Bengal*	315	242	117	-	99	26
Total	20,322	17,103 [100]	10,682 [62.5]	90 [0.5]	1,672 [9.8]	4,659 [27.2]
Western Himalayas						
Himachal Pradesh	5,567	3,404	1,049	1,194	568	593
Jammu & Kashmir	22,224	4,505	2,747	126	734	898
Uttaranchal	5,113	5,060	3,430	254	660	716

(Contd.)

(Table 2.6 Contd.)

State	Total geo-graphical area	Reporting area	Forests	Permanent pastures & grazing lands	Net area sown	Others
Punjab*	383	383	38	11	116	218
Haryana*	213	213	123	-	68	22
Total	33,500	13,565 [100]	7,387 [54.5]	1,585 [11.7]	2,146 [15.8]	2,447 [18.0]
Total Himalayas	53,822	30,668 [100]	18,069 [58.9]	1,675 [5.5]	3,818 [12.4]	7,106 [23.2]
Non-Himalayan region	2,74,904	2,74,223 [100]	50,757 [18.5]	9,379 [3.4]	1,38,397 [50.5]	75,690 [27.6]
All India	3,28,726	3,04,891 [100]	68,826 [22.6]	11,054 [3.6]	1,42,2158 [46.6]	2,796 [27.2]

Figures in [ ] indicate per cent of reporting area.

* Source GoI (1998)

The net cultivated area is higher in the western Himalayan region (15.1% of the total geographical area) than in the north-eastern region (9.1%). The net cultivated area varies from 2.7 per cent in Arunachal Pradesh to 40.9 per cent in Darjeeling district of West Bengal. Forestry is the major landuse in the mountains covering about 59 per cent of the total reporting area as against 19 per cent in the non-Himalayan region and 23 per cent for the whole country. About 12 per cent of the region is under permanent pastures and grazing lands.

In a more recent publication of the demographic database of Indian Himalayas (Nandy, S.N. et.al. 2000), the decadal growth rate of IHR is observed to be alarming high (29.05%) as it is much higher than the nation's growth rate (23.85%) during 1981-91.This increased population growth with high non-working population may be additionally responsible for the rapid environmental degradation in the mountain region.

Excessive utilization of natural resources are creating conflicting situations for sustainable development in the mountain region. The extensive network of National Agricultural Research Systems in the region has evolved a large number of technologies for efficient management of natural resources and increasing the agricultural

productivity. These technologies have been disseminated by government agencies which have shown marked improvement in the socio-economic conditions of the people. However, there exists a vast scope for identifying strengths, weakneses, opportunities and threats for improving the productivity of agro-ecosystems. Particular emphasis is needed on the development of ecology and environment keeping in mind the issues connected with eco-restoration, eco-preservation and eco-development in all parts of the Himalayas. These measures will reduce their adverse impact on the mountain ecology as well as the fertile Indo-Gangetic plains.

2.2 BASICS OF AGRO-ECOSYSTEMS AND FUNCTIONS

An agro-ecosystem is essentially a man-made ecosystem which is geared up to meet the basic human needs of food, fodder, fuel, fertilizer, fibre and small timber as well as medicinal and commodity crops. An agro-ecosystem or simply an ecosystem is the most complex level of organization in nature. It is made up of a biotic community (living) and it's a-biotic (non-living) or physical environment, including climate, soil, water, air, nutrients and energy. Ecologists who try to link together and analyze the many different physical and biological activities in an environment are known as *system ecologists.* Their studies often focus on the flow of energy and the cycling of materials through an ecosystem. Sometimes powerful computers are also used to understand the research data on the above aspects.

2.2.1 Energy Flow

Ecologists categorize the elements that make up or affect an ecosystem into six main parts, based on the flow of energy and nutrients through the system:

(i) The sun
(ii) Abiotic substances
(iii) Primary producers
(iv) Primary consumers
(v) Secondary consumers and
(vi) Decomposers.

The sun provides the energy that *primary producers* need to make food. Primary producers consist mainly of green plants such as grass and trees, which make food by the process of photosynthesis. Plants also need *abiotic substances*, such as phosphorous and water, to grow.

Primary consumers such as mice, rabbits, grasshoppers and other plant-eating animals, foxes, weasels, and other *secondary consumers* or predators–eat animals. Decomposers, such as bacteria and fungi break down dead plants and animals into simple nutrients. The nutrients go back into the soil and are used again by plants.

The series of stages that the energy goes through in the form of food is called a *food chain.* A simple food chain would be one in which grass is the primary producer. A primary consumer, such as, a rabbit, eats the grass. The rabbit in turn, may be eaten by secondary consumer, such as a fox or a hawk. Decomposing bacteria break down the uneaten remains of dead grass, rabbits, foxes and hawks, as well as the body wastes produced by the animals in the food chain.

Most ecosystems have a variety of producers, consumers and decomposers, which form an overlapping network of food chains called a *food web.* Food webs seem especially complex in many tropical and oceanic ecosystems. Energy moves through an ecosystem in a series of transformations. First primary producers change the light energy of the sun into chemical energy that is stored in plant

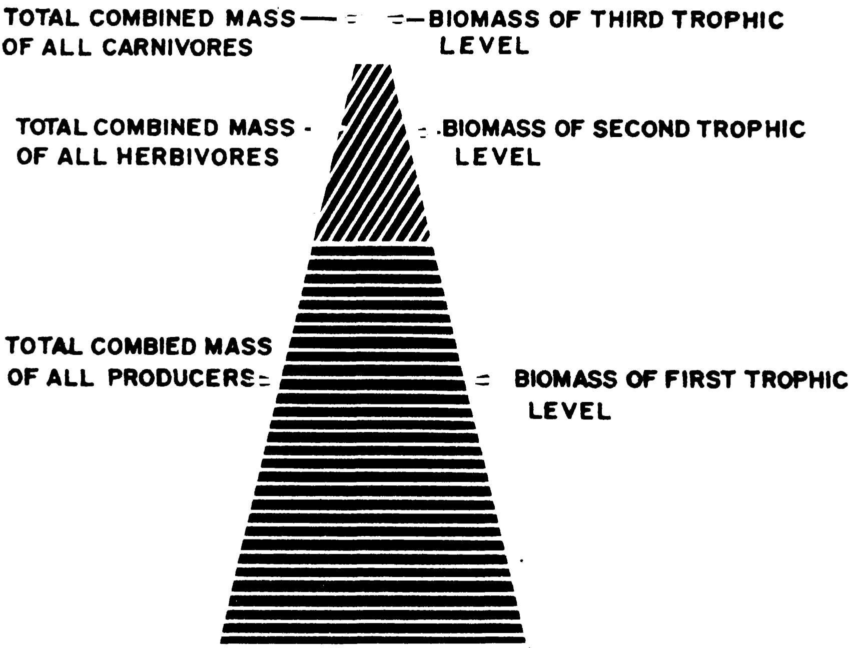

Fig. 2.2.1 Biomass Pyramid. A graphical representation of the biomass (the total combined mass of organisms) at successive trophic levels has the form of a pyramid.

protoplasm (cell material). The energy stored in plants is then transferred to other organisms in the form of food. Primary consumers change it to a different kind of chemical energy and store it in their body cells. This energy changes again when the secondary consumer eats the primary consumer.

Most organisms have a low ecological efficiency. This means that they are able to convert only a small fraction of the available energy into stored chemical energy. For example, green plants can change only about 0.1 to 1 percent of the solar energy that reaches them into plant protoplasm. Most of the remaining energy is turned up during plant growth and escapes into the environment as heat. Similarly, *herbivores* (plant-eating animals) and *carnivores* (meat-eating animals) convert into their own body cell about 10 to 20 per cent of the energy produced by their food.

Because so much energy escapes as heat at each step of the food chain, all ecosystems develop a *pyramid of energy* (Fig. 2.2.1) Plants (primary producers) form the base of the pyramid. Herbivores (primary consumers) make up the next step and carnivores (secondary consumers) form the top. The pyramid reflects the fact that more energy passes through the plants of the ecosystem than through herbivores, and even less energy flows through the carnivores. In many land ecosystems, the pyramid of energy results in a *pyramid of biomass*. This simply means that the combined biomass (weight) of the plants is greater than the combined weight of the herbivores, which in turn exceeds the total weight of the carnivores.

2.2.2 Cycling of Materials

All living things are composed of certain chemical elements and compounds,the chief among them are *water, carbon, hydrogen, nitrogen, oxygen, phosphorous* and *sulphur.* All of these materials cycle through ecosystems again and again.

The cycling of phosphorus provides an example of this process. All organisms require phosphorous, plants to take up phosphorus compound from the soil, and animals get phosphorus from the plants or other animals they eat. Decomposers return phosphorus to the soil. In natural undisturbed ecosystems, the amount of phosphorus remains fairly constant. But when an ecosystem is disturbed by human activity, the phosphorous often "leak out", reducing the ability of the ecosystem to support plants. One way people alter the phosphorus-cycle, is by

replacing forests with farmland. Without the protection of the forests, phosphorus is eroded from the soil and swept away into rivers and lakes. There, it often causes undesirable excess growth of algae. Eventually, the phosphorus becomes locked in sediments at the bottom of lakes or the sea. Because of this loss of phosphorus, farmers must use costly fertilizers to put the element back into the soil.

2.2.3 Changes in Ecosystems

The changes in ecosystems occur daily, seasonally and in case of ecological succession, over a period of many years. Sometimes changes take place severely and abruptly whenever a fire sweeps through a forest or a cyclone batters a seashore. But most of the day-to-day changes, especially in the nutrient cycle, are so subtle that ecosystems tend to appear stable. This apparent stability among plants and animals and their environment has been called the "balance of nature". In the past, this concept of balanced, largely unchanging ecosystems was thought to be especially, descriptive of climax communities. But because these earlier views were based on short term studies, they were found to be incomplete. Now that ecologists have had an opportunity to study ecosystems over longer periods, they have had to alter some of their ideas.

Natural systems are filled with compensating mechanisms that help to stabilize nature. Thus populations often need to be understood from the perspective of the entire ecosystem and this needs a multi-disciplinary and coordinated approach to understand the nature. We may recall that nature possesses a dual personality. When properly respected and understood, nature can act as a perennial provider, but, when abused and degraded, nature can be a tyrant and adversely affect the human society. Francis Bacon wrote in 1620 A.D. that *"Nature to be commanded must be obeyed"*.

For almost all forms of life of the lowland biota, the high altitude is inhospitable in the extreme, for many of the lowland animals it proves to be a veritable graveyard. Yet, we have seen that the high altitude region is alive; a variety of organisms exist in complete harmony with these very unfavorable conditions.With increasing elevation the system are characterized by lower rate of aboitic,biotic and cultural exchanges, slower rate of growth, slower aging and late maturity,poorer reproductive efficiency, and higher resistance. An astonishing group of plants and animals have apparently succeeded

in adjusting their vital functions so as to enable them to exist at high altitude. How has this been possible for them, when particularly man, with his unique capacity to shape his own special environment, seems to have completely failed. (Mani, M.S. and Giddings, L.E., 1980).

In classical biology, it is the general fashion to speak of the origin and evolution of individual organisms in total isolation of others and from their habitat. We believe, however, that evolution of an organism is only an infinitesimally small phase of the evolution of its ecosystem as a whole. *The origin and evolution of the high altitude organisms are integral parts of the evolution of the high altitude ecosystem* – of the birth and rise of the mountain itself. The high altitude plants and animals, now found on the mountain, are in harmony with the high altitude environment not only because they are essential parts of the environment, but also because they formed an integral part of the very process that shaped the environment. The same process brought them and the mountain into existence at the same time.

Unlike the evolution *in situ* of the high altitude organisms, human evolution was not isochrone with the uplift of the mountain systems, on some of which he may be resident today. As is well known, nearly all the important present-day high mountain ranges of the world are products of the Tertiary orogenic activity, but the differentiation of *homosapiens* as a distinct species, did not come about until perhaps the late Pleistocene. When man actually appeared on the scene, even the youngest mountains were thus already 'as old as the Earth' for him.

This explains his total lack of distinctive high altitude specializations; he is not an integral product of the high altitude ecosystem, but merely an intruder in it. As an intruder, man alters the ecosystem and disturbs the harmony and finds himself in disharmony with nature. Even 'perfect acclimatization' produced by prolonged residence of centuries on high mountains, is basically a pathological state and would by no means entitle him to be considered as a hypsobiont animal.

2.3 CHANGING DEVELOPMENT DILEMMA IN HIMALAYAN REGION

Immediately after India's independence, the development of the Himalayan region was taken up as a top priority by Pandit Nehru, the first Prime Minister of India. India Meteorological Department (IMD) brought forward the idea of establishing a High Altitude Research

Station for multi-disciplinary research in Himalayas (Dhir, R.D., 1952). In 1978, National Seminar on Resources, Development and Environment in the Himalayan Region indicated the existence of policy gaps (Anon,1978) Two important recommendations were:

(i) A high level multidisciplinary group be set up to identify gaps in the ongoing research, design and development pertaining to the Himalayan region and also to identify appropriate financial arrangements for supporting further activities that need to be taken up.

(ii) Initiating a programme on long-term research into the functioning and dynamics of the Himalayan Ecosystems.

After a long gap,the Planning Commission decided to appoint an Expert Group to formulate a National Policy on the Himalayas for Integrated development (Anon, 1993). The group recommended :

(i) To establish a Himalayan Development Authority (HDA) under the Prime Minister to assure continued high level intervention for integrated development of Himalayas.

(ii) To create a National Himalayan Environment and Development Fund (NHEDF) to promote the linkage in natural sciences with social sciences and to guide the operation of national policy for integrated development of the region.

In a very competent review on the Himalayan Dilemma – Reconciling Development and Conservation, (Ives, J.D. and Misserli, B., 1989) gave the theory of Himalayan Environmental Degradation (popularly known as EDT – Environmental Degradation Theory) with the following conclusions:

(i) the population explosion was due to the introduction of modern health care and medicine and reduction of diseases

(ii) the increased population in the sustenance of mountain societies has led to (a) reduction of land per family (b) deepening poverty and (c) massive deforestation.

(iii) that such deforestation will result in total loss of all accessible forest cover in the countries existing in Himalaya in the near future.

2.3.1 Prehistoric Settlements in Himalayas

Himalayan ranges are one of the cradles of human civilization. The mountain ranges enjoyed free flow of men, material, knowledge and

culture through Hindu Kush in the west and Naga, Patkoi and Surma series in the east.

The knowledge about the patterns and the extent of prehistoric settlements in Himalayas is also sparse. Whatever is available is mainly based on the Sanskrit epic literature which has been largely derived from oral tradition. Such literature is said to be modified several times before being actually committed to writing (O'Flaherty, W., 1975) The British writings describe three patterns of settlement in Indian Himalaya :

- The western Himalaya was widely settled from 1500 BC onward by a population of nomadic warriors called *Khas* who were part of a succession of waves of Aryan migration into India from north-west. The Khas have subjugated the Indian inhabitants relegating them to a rigidly inferior social status. The Khas gradually became accultured to the predominant Hindu influences of the northern plains.
- In the central and eastern Himalaya, the settlers seem to be the migrants of Tibetan–Burman tribals from south-east Asia, sometimes in the early millenna BC. The Sanskrit writing described them as *Kirata* and were said to be great hunters, skilled in arts of magic and practiced cannibalism.
- In the higher reaches of Himalayas, the settlements of *Bhotias* and related people, dating from the early century AD, are said to be settlers from the successive waves of nomads transforming in the process to a more settled life combining agriculture, pastoralism and trade.

Stiller, L.F. (1975) reports that during the Gorkhali conquest, late in the eighteenth century, there were about eighty separate principalities between the Sutlej and present-day Sikkim. The study of population characteristics (Karan, P.P., 1987) defined five mountain cultural regions in the Himalaya and between 1901 and 1981, the population of these regions trebled from 11 million to over 33 million.

The region provides the life-support base for about 50 million mountain people and probably in excess of 450 million people of the plains–the very densely populated areas of the Indus, Ganga and Brahmaputra and middle Jiang (Sichuan Basin) which constitutes a significant portion of humankind.The human habitation in the Himalayas is spread over three altitudinal zones viz high altitude (over 2700m);middle altitude (between 1800 and 2700m) and low

altitude (below 1800m).The high altitude zone is characterized by an arid to semi-arid climate with extremely cold winters. Vegetative growth is very small. Settlements are very small and the people of this zone are usually of Mongoloid origin. Their main source of livelihood is pastoralism. Agriculture is carried out in small patches, wherever the land is able to produce a crop of course cereals in the short growing period that is available. Seasonal migration is an interesting character of most of the people living in this zone. They move up to the high altitude pastures with their animals during the summer months and return to lower elevations once the autumn sets in.Thus these communities live a nomadic or semi- nomadic existence. Cultivation is carried out in small patches of fertile lands. They depend upon snow-melt water for irrigating their crops.The short growing season restricts the number of crops in a year to one. Agricutural activity comes to standstill during the winter months due to the severe cold and hence many of them migrate to the lower hills or to the plains. Some of the high altitude communities of the Himalaya are the Ladakhis, Zads, Pangwals, Bhotias, Khambas etc. Life is not so harsh for the people living in the middle altitude zone. Rainfall is fairly heavy and the people are able to grow at least two crops in a year river terraces and small fields formed by terracing the land. There are a few communities living in this zone who depend on pastoralism for their livelihood. They are semi-nomads.The settlements of this zone are either agglomerated or dispersed type and located on hill slopes or on the valleys.These people keep contact both with high altitude communities and with the people living in the low altitude zone. Some of the main communities residing in this zone are the Muslim communities of Kashmir, Jaunsaris of Dehradun, Bhotias and Gurkhas of Nepal, Lepchas of Sikkim, and Aka, Apatani and Miniang of Arunachal pradesh. The people residing in the low altitude zone enjoy the best conditions having fertile lands and irrigaton facilities,large network of roads and nearness to markets of fairly big towns for selling their produce. Rainfall in this zone is fairly heavy and the cultivators are able to obtain at least three crops in a year. In terms of modern definition of development paradigms, the whole of the Himalayan area also embraces one of the world's greatest accumulation of poverty, malnutrition and accelerating population growth (Rao, K.S., 1997). Given the enormous range of altitude in a short north-south horizontal distance, reduces the outbursts of cold

air from Central Asia and ensures the northern peninsula of India has warmer winters than otherwise be the case. It also harbors a wide range of phyto-geographic regions and floral/faunal assemblages, making it a rare gift of nature but these natural blessings are wrapped in a very difficult package for management by human civilization.

2.3.2 Natural Resources Management-Development and Conservation

Production, consumption, preservation and distribution are the key processes characterizing resource dynamics. They are also used as social, economic indicators of development for a given region.

In general, we have to consider the following strategies for development of natural resources in the Himalayan region:

(a) Promotion of Horticulture

Horticulture in the mountain region is a natural gift and an economic necessity because it has the potential not only to stabilize the agricultural economy but also to simultaneously promote environmental conservation of the region concerned. It is, therefore, a need of the time to give greater stress on the promotion of horticulture.

(b) Agroforestry Farming

Since the forest tree cover is declining at an alarming rate, essential sources of food, fodder and many other products are disappearing and ultimately soil and water base for food production is being degraded. Solutions, therefore, are urgently needed to safeguard the land from this degradation. Agroforestry farming is an age-old practice in hills, it needs to be further strengthened.

(c) Restoration of Wastelands

Restoration of the wasteland resource has emerged to ensure improvement in the quality of physical and human environment in an integrated manner.

(d) Ensuring People's Participation

People's participation is necessary for developmental activities which may ultimately bring out a reduction in investment by the developmental agencies. Establishing successful and harmonious partnership with the village community is of paramount importance as by using such parameters, the people will be organized and

gainfully engaged. They will be able to express their own choices for decisions based on their long traditional knowledge.

2.3.3 Sustainable Development of Mountain Agriculture

According to UN estimates, about one tenth of the world population lives in the mountain areas, even though large parts of them are subjected to ecological ,economic, and social problems (Rieder, P. and Wyder, J.,1997). On the sustainable claim for mountain areas according to Rio,1992, the situation is now brought into sharp focus by the demand for long term sustainable exploration of mountain regions by UNCED. Research and politics are challenged to elaborate and realize long-term solutions. If this does not happen, mountain areas are in danger of short-term exploitation as a first step, and abandonment as a second.

The sustainable concept of the Rio Summit,1992 declaration contains the following three components:

(a) Ecology;
(b) Economics;
(c) Social Issues.

The underlying values of these three components must be realized (Fig 2.2.3.1), according to Agenda 21, to the highest measure possible

(i) The *ecological component* represents the natural (i.e. physical) state of the environment which should not be degraded. This implies that erosion, increased slope instability, loss of soil fertility, increase in chemical residues, loss of biodiversity, excessive forest cutting, over-grazing, soil, water and air pollution, and over-use, should be prevented.

(ii) The *economic component* represents a productive economy aided by technological know-how, a modern infrastructure, and other factors. Local industries must be competitive and offer employees a satisfactory salary. Such business structures must ensure that unemployment will not increase and that the economy will strengthen.

(iii) The *social component* comprises the different societal factors as, for example, well-planned demographic structures, appropriate real incomes with sufficient purchasing power, secure working and having conditions, social institutions and finally, a sense of value in the daily

life of the population – a life without war, oppression, and need, and also a viable local culture and education.

Governments and external donors should focus their effort on the promotion of semi-commercialization, which will draw people away from the agrarian sector while increasing the value of local agricultural raw products and local trade. Investment funds must be introduced to establish installations for processing, refinement, storage, conservation , vehicle maintenance, and infrastructure in rural areas. Only through a reduction in the over-exploitation of the fertile agricultural areas can all three components of sustainability gradually become positive.

The World Commission on Environment and Development (WCED, 1987) adopted the following definition on Sustainable Development (SD):

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The critical objectives of SD are reviving growth; changing the quality of growth; meeting essential needs for job, food, energy, water and sanitation; ensuring sustainability level of population; conserving and enhancing the resource base; reorienting technology and managing risk; merging environment and economics in decision making; reorienting international economic relations and make development more participatory.

The World Conservation Strategy (WCS) suggested three ecological principles for ecological sustainability viz. maintenance of essential ecological processes and life support systems; the preservation of genetic diversity and the sustainable utilization of species and resources.

It may be noted that the sustainable environmental management recognizes three conservation rules (Turner,R.K.,1988) for efficient use of natural environmental assets:

(i) *Maintenance of the regenerative capacity of renewable resources and avoidance of excessive pollution which could threaten bio-spherical waste assimilation capacities and the life support system.*

(ii) *Guidance of technological changes in an indicative planning process such that wherever physically possible, switches from non-renewable to renewable resources are fostered.*

(iii) *Utilization of the growing body of the scientific data on geological and geo-chemical processes in order to formulate a phasing policy for the use of non-renewable resources.*

Sustainable Development provides a unique opportunity to narrow down the differences between environmentalists and development activists to tackle a myriad of problems facing us today. It allows us to explore what patterns and levels of resource demand and use will be compatible with different forms or levels of ecological and social sustainability, and with different notions of equity and social justice. SD provides more flexibility and diversity of approaches in developing strategies that might lead to a society living in harmony with the environment and with itself. Ismail Serageldin and Andrew Steer (1994) gave new paradigms for progress by promoting environmentally sustainable development. Under their leadership, the World Bank defined the idea of environmentally sustainable development (ESD) by a triangular framework (Fig. 2.3.3.1).

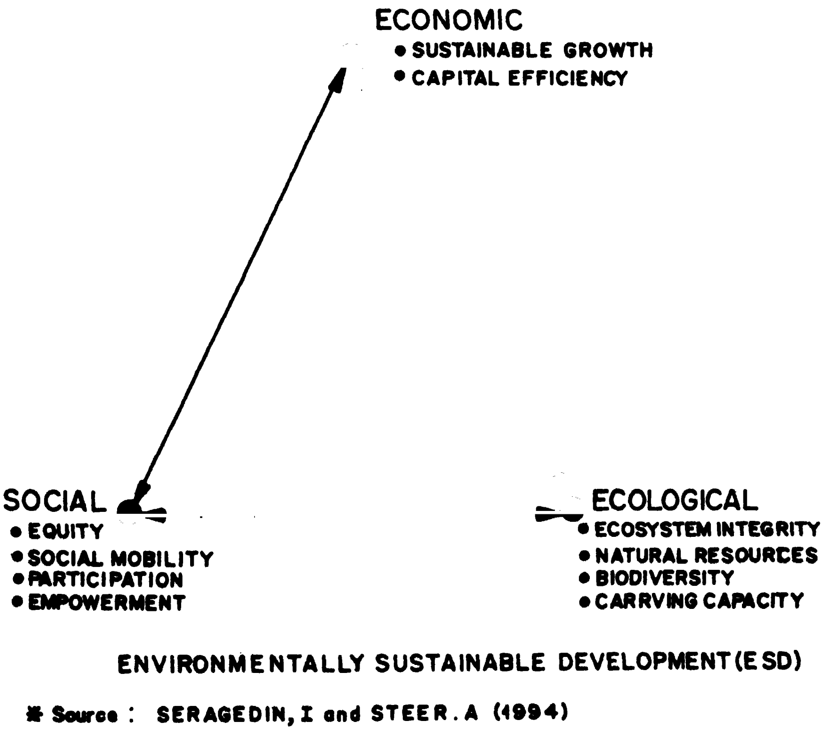

Fig. 2.3.3.1 Environmental Sustainable Development (ESD)

Mountain agriculture is the dominant system for natural resource use. It broadly covers all land-based activities such as, cropping, animal husbandry, horticulture, and forestry. It can be perceived as an integrated system of natural resource use, along with its man-made support facilities. The pace and pattern of agricultural transformation, as well as its performance, in mountain areas is conditioned by the biophysical features of these areas and the human ability to adapt to them. The interrelated key features include restricted accessibility, fragility, marginality, diversity, specific niche, and a combination of steep slopes and altitudinally reduced temperature. These features create objective circumstances which in turn, present a range of opportunities and constraints and human responses directed to use of the mountain resources. (Jodha, N.S., 1997).The problems of sustainable agriculture in Hindu Kush – Himalayas (HKH) are addressed in a recent publication entitled 'Pathways Towards a Sustainable Mountain Agriculture of the 21st Century–The Hindu Kush-Himalayan Experience (Rhoades, R.E., 1997). Among the innovations suggested by the author are the introduction of a Mountain Agricultural Systems and Societies' Information Files (MASSIF) project which involves computerized mapping of mountain agricultural systems and societies based on government statistics, ethno-data (ethnographic and ethno-biological), grey-literature, and non-conventional sources of information. Among the excellent recommendations to promote sustainable mountain agriculture in the 21st century, the establishment of a mountain source, a composite of disciplines applied to mountain research and development, namely *montology* (part humanities, part social sciences, part natural sciences, part policy sciences and part folk sciences) is strongly recommended by the author as a means of ending for once and for all, the marginalisation of this extremely important and endangered ecosystem and all of its inhabitants. The author listed eight steps towards sustainable mountain agriculture in the HKH:

(*i*) *revisit* critically Himalayan dilemmas and mountain perspectives,

(*ii*) *contextualise* the concept sustainability in mountain agriculture,

(*iii*) *scale* the social and spatial hierarchies relevant to sustainable agriculture,

(*iv*) *map* and systematically collect data on the agricultural systems and societies of the HKH,

(*v*) *trace* carefully the linkages between farming, poverty, and the mountain environment,

(*vi*) *link* land users, scientists, development professionals, and policy makers through stake-holder and perceptional analysis,

(*vii*) *design* an approach for working with the learning from mountain peoples on their terms, and

(*viii*) *prepare* an action plan for Mountains in the New Millennium.

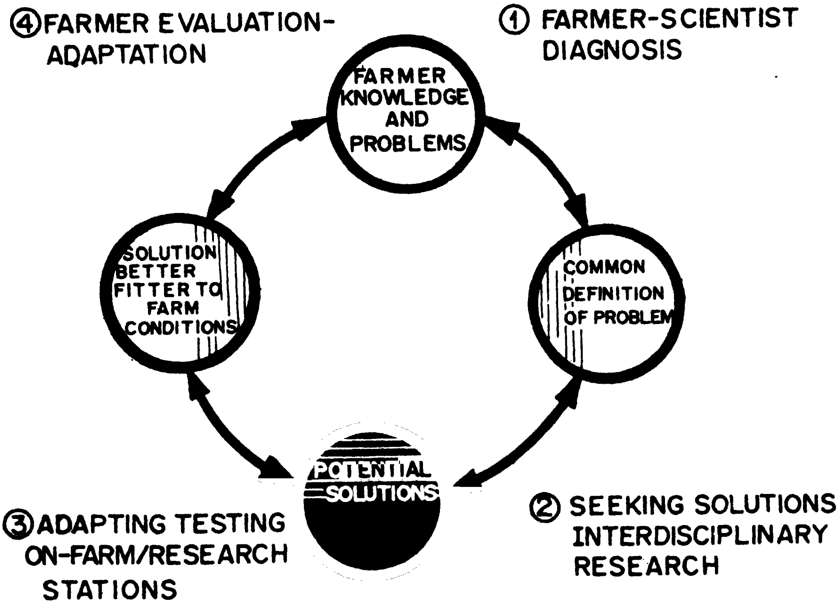

Fig. 2.3.3.2 Farmer - Back – to – Farmer Model of Adaptive Research.

We need conceptual models (Fig. 2.3.3.2) and empirical research to link the past with the future, between traditional and modern, between local and global and between people's aspirations and society's needs. Prowling (i,e,. roam stealthily,especially in search of prey or booty) process of natural resources in Himalayan region is resulting in deculturisation, dehumanization, deforestation, desertification and the loss of biodiversity to the mankind. This has to be halted for initiating the regeneration processes in the region evolving conscious relationships between the people and the development agencies.

2.3.4 Sustainable Mountain Tourism

Tourism is defined as activities of people who travel outside their usual environment for leisure, business and other purposes, while eco-tourism has been defined as responsible travel to natural areas that conserve the environment and sustain the well-being of local people. Sustainable tourism means traveling with an awareness of our larger impact on natural resources. This has to be remembered by all players including government promoting tourism, tourism businesses and tourists themselves. Together, these groups will need to balance the ultimate goal of satisfying tourists' demands with key environmental and social objectives, such as, reducing resource consumption, eliminating poverty, and preserving cultural and biological diversity (Mastny, L. 2002).

Tourism is one of the world's least regulated industries which has serious implications for eco-systems, communities and cultures around the world. Hotels, tourist transport and related activities consume huge amounts of energy, water and other resources and generate pollution and wastes, often in destinations that are unprepared to deal with these impacts. Tourism industry has a great employment potential and a large foreign exchange earner for the host country. It provides major opportunities and challenges for institutions and individuals at all levels whether they belong to government, NGO or public sector institution. As a fast growing activity, it has become a major vehicle for development of mountain regions.

The Himalayan region is considered to be abundantly suited for tourists, as it offers all kinds of attractions. It has attracted people – pilgrims, ascetics, naturalists, explorers, mountaineers, trekkers and cultural tourists from far and wide due to their breath-taking natural and scenic beauty and rich diversity of culture, flora and fauna. Gangotri and Gaumukh, the source of the Ganga, along with Yamnotri, Kedarnath and Badrinath form the four most important pilgrimage centres in Garhwal region. Hundreds of other noteworthy shrines are located throughout the Himalayan heights. In many ways, the Himalaya represent the soul and the spirit of India. Millions of people visit religious sites every year and their number is increasing. It is observed that local ethics, culture and ethos of conservation in Indian Himalayas are facing an onslaught as a result of huge transitory tourist population. It is estimated that a number of foreign and Indian tourists have been increasing 4-6 times every five years during last

TABLE 2.3.4.1*

Types of tourism and implications for environment, economy and society in rural mountain areas

Trekking/Mountaineering	*Resort Tourism*	*Cultural Tourism*	*Pilgrimage Tourism*
Environmental	**Environmental**	**Environmental**	**Environmental**
• Forest degradation due to increased demand for fuel-wood along trails	Land use problems brought about by sprawling growth of resorts	• Most cultural tourist confined to or based in major settlements or urban areas with historic, cultural monuments and relics so little direct impact on the environ-ment except for tourist litter generated in thise sites	• Heavy concentration of pilgrims during parti-cular periods creating problems of waste disposal, pollution and congestion; heavy demand for fuel wood during these periods
• Trail degradation along heavily used trails	Deforestation/forest degradation due to demand for fuel wood and timber		
• Pollution in and around campsites, wanton disposal of non-degradable waste	Soil instability and degradable and to heavy construction along slopes		• Many pilgrim sites in biologically sensitive, fragile environments
• Contamination of creeks, rivers and water sources, pollution of soils and glaciers at high altitudes	Discharge of untreated sewage and solid waste along slopes and rivers	**Economic** • Some income to rural households from the sale of local handicrafts and other souvenirs	• High pressure on basic infrastrcture during pilgrimage season
	Traffic congestion, noise and vehicular pollution along popular resorts	• Employment and income due to the revival of	**Economic** Traditional pilgrimage

(Contd.)

(Table 2.3.4.1 Contd.)

Trekking/Mountaineering	*Resort Tourism*	*Cultural Tourism*	*Pilgrimage Tourism*
		traditional crafts caused by the demand from tourist	based on frugal living that exerted little pressure on local economics
Economic • Direct income to rural households operating lodges, or using mules/yaks for transporting provisions, or those engaged in portering during the tourist season. • Some impact on production regime due to tourist demand • Inflation and dependency • Growth of central settlements **Social/cultural** • Demonstration effect • Cultural awareness	**Economic** Some income to rural households due to demand for local agricultural and livestock produce • Some local employment during the tourist season **Social/cultural** • Demonstration effect • Social aberrations/problems resulting from unscrupulous tourist and resort operators	**Social-cultural** • Commercialization of art, culture and religious symbols • Theft of cultural, religious artifacts and black marketing • Breakdown of cultural inhibitions and erosion of cultural heritage • Openness to new ideas	• Easy access to many pilgrimage sites resulting in unscrupulous 'mass' tourism and high dependence on imports • Some income to local households from the sale of local handicrafts **Social-cultural** • Commercialization of religious rituals and symbolism

* Source : Sharma, P. (2000)

few decades. This has created acute problems of litter, vehicular pollution, waste disposal, erosion, destruction of flora and fauna. Different types of tourism, such as mass tourism to cultural tourism, health tourism, eco-tourism and immense range of types of sports tourism, have been evolved. A number and types of mountain activities have increased dramatically in recent years, such as sight seeing, hiking, hunting, fishing, climbing, skiing, horse-back riding, camping, canoeing etc. Table 2.3.4.1 presents a general picture of the implications of different types of tourism on the environment, economy, and society of rural mountain areas in the Himalaya (Sharma, P., 2000).

Recent debates on mountain tourism and conservation of biological and cultural diversity for a sustained mountain economics have identified following key actions:

(i) Tourism Development Planning should be integrated with community development and conservation plans in order to promote a diversification of livelihood opportunities in mountain areas rather than an over-dependence upon tourism.

(ii) Equitable distribution of benefits and opportunities among mountain tourism stakeholders and improved well-being of mountain people, is possible with the diversification of mountain economics that increase the benefits retained by mountain communities, recognition of land and resource rights of indigenous people and by carefully blending traditional knowledge with appropriate technologies.

(iii) Conservation of biodiversity of mountain regions by raising awareness of all stakeholders about the value of biodiversity and recognition of the cultural and religious values and restrictions on areas of biodiversity associated with sacred sites and the empowerment of local communities with management responsibilities.

(iv) Conserving cultural diversity and heritage of mountain people by respecting the spiritual and cultural norms of local culture. Vulnerability of sacred sites to impacts of tourism need assessment to develop appropriate plans for tourism development and management to be carried out by local communities with support from government and NGOs and user fees.

Future of mountain communities must be addressed holistically and strategically. This will require a move beyond current and well-known approaches which have tended to be rather myopic, sectoral and geographically limited. It also implies that the involvement of not only professional planners and policy makers, but also tourism industry and the diverse stakeholders involved in mountain communities, from the earliest stages of issue definition through to the implementation and monitoring of policies (Price, M.F.et al 1997).

Chapter 3

ATMOSPHERIC ASPECTS

3.1 INTRODUCTION

We all know that atmosphere is the gaseous envelope which surrounds the Earth. The total mass of air is about $6x10^{18}$ kg. The atmosphere extends to about 100 km. of height, surrounding the earth (radius 6378 km). It is most important organ of the earth system for the existence of life and is sometimes compared with the skin on our body.

The main natural constituents of atmospheric air are Nitrogen (78%), Oxygen (21%) and Argon (0.9%) while the minor constituents are Carbon Dioxide, Neon, Helium, Hydrogen, Xenon and Water Vapour. It also contains pollutants e.g. Carbon Dioxide, Methane, Chlorofluorocarbons (CFCs) and Methyl Chloride, Carbon Monoxide, Nitrous Oxide, Sulphur Dioxide and dust particles.

Based on the temperature distribution, the vertical atmosphere (Fig 3.1.1) is divided into *troposphere* where the temperature decreases with altitude at an average lapse rate of 6.5°C/km. The upper surface of the troposphere is the *tropopause*. It's altitude is 16 km in tropics; 12 km in mid latitudes and 8 km around poles and contains 75% of total air.Above the tropopause and upto 30 km the temperature either remains constant (isothermal layer) or rises slowly. Beyond 30 km, the temperature increases faster upto 50 km *(stratopause)*. The atmosphere between the tropopause and the stratopause is called *stratosphere,* containing about 24% of air. The convective currents and moisture, usually, do not cross the tropopause.

The temperature remains constant in the layer 50-55 km, and decreases thereafter up to 80 km. This layer from 50 km to 80 km is called *mesosphere* and its roof as *mesopause.* The temperature at the mesopause is -80°C to -90°C. The region absorbs lower frequency radiowaves.

Above the mesopause, the atmospheric layer up to 500-600 km

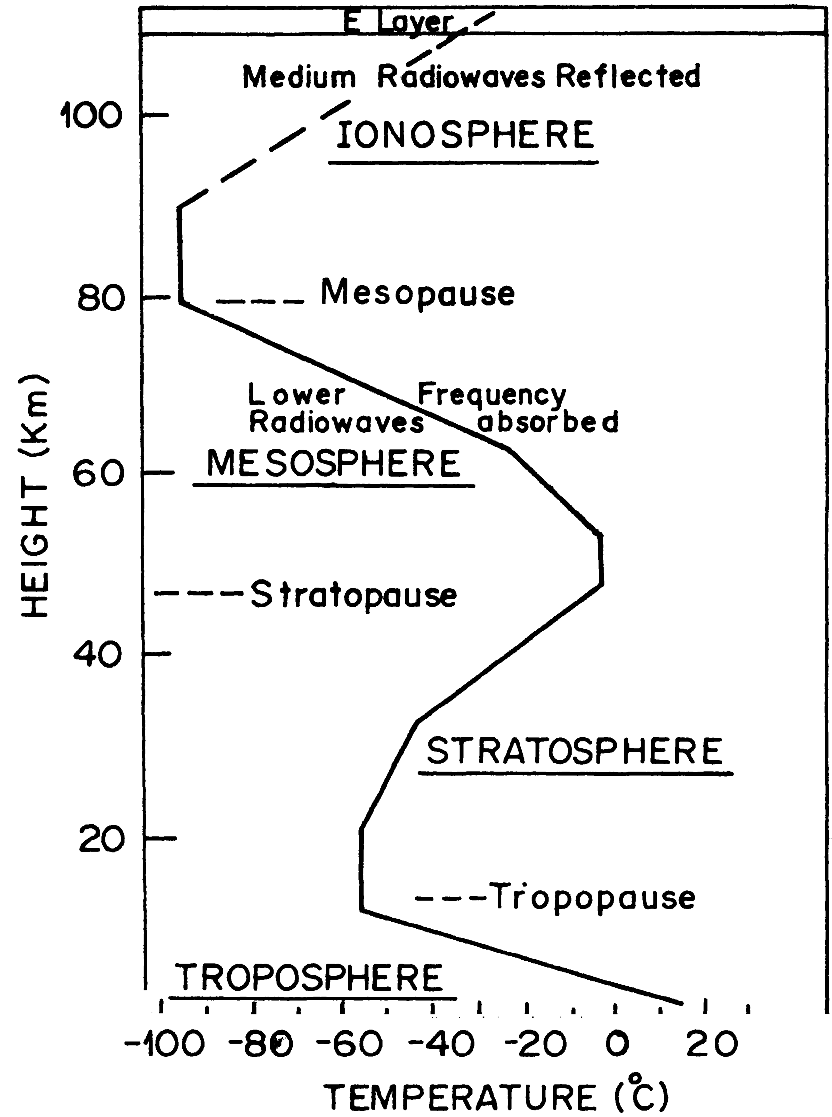

Fig. 3.1.1 Vertical Structure of Atmosphere

is mostly in an ionized form, having free electrons under the action of ultraviolet rays. This layer ((80-600 km) is called the *ionosphere* having two significant layers with high electron density; E-layer around 100 km and the F-layer between 250 and 350 km.

Weather is the state of the atmosphere at a particular time , as defined by various meteorological elements (e.g. pressure, temperature. humidity, wind, cloudiness, rain or snow fall). The

climate is the synthesis of weather conditions for a given area.It is characterized by long term statistics (mean values, variances, probabilities of extreme values etc.) of the meteorological elements in that area.

Atmospheric phenomena over the mountains display a hierarchy of spatial and temporal scales as illustrated in Table 3.1.1 (Stone, P.B., 1992).

TABLE 3.1.1

Scales in Mountain Weather and Climate*

Features	*Micro Scale*	*Local Scale*	*Regional Scale*
Meteorological Phenomena	Turbulent Motion (Gusts)	Slope and Valley Winds;	Thunderstorm Cluster, Synoptic System Fall winds
Landscape Elements	Rocks, Vegetation Clumps	Terrain Elements (Slopes, Valleys)	Mountain Range Plateau
Climatic Features	Snow Patches	Sunny/Shaded Radiational Contrasts, Thermal Belts	Plateau, Monsoon

* Source: Stone, P.B., 1992

The mountain influences on climate and related environmental features are the result of four basic factors: altitude, continentality, latitude and topography, each of which affects several important meteorological variables. (Table 3.1.2).

TABLE 3.1.2

Climate Effects of the Basic Mountain Climate*

Factors	*Primary effects*	*Secondary effects*
Altitude	Reduced air density, vapour pressure; solar radiation receipts; lower temperature evaporation; physiological stresses	Increased wind velocity (mid-latitudes); increased precipitation (mid latitude);

(Contd.)

(Table 3.12 Contd.)

Factors	*Primary effects*	*Secondary effects*
Continentality	Annual/diurnal temperature range increased; cloud/ precipitation regime modified	Snow line altitude rises
Latitude	Day length and solar radiation total, vary seasonally	Snowfall proportion increases; annual temperature decreases
Topography	Spatial contrasts in solar radiation/ temperature regime; and precipitation as a result of slope and aspect.	Diurnal wind regimes; snow cover related to topography.

* Source: Stone, P.B., 1992

In general, there is a paucity of mountain meteorological data and a sparse station network which has limited our understanding of mountain weather and climate. Variations of atmospheric circulations in space and time scales could be broadly classified for observation network spacings. (Table – 3.1.3)

TABLE 3.1.3

Space and Time Scales in Atmosphere*

Motion	*Space Scale(km)*	*Time Scale*	*Network Spacing*
Microscale	10^{-3}	Sec - min.	cm – m
Gravity waves	< 1	min - hr.	M – km
Mesoscale	5 – 10	hr.	5 – 10 km
Small Synoptic	100	hr - day	100 km
Large Synoptic	100 – 1000	Days	100 – 500 km
Planetary	> 1000	days – weeks	500 km

* Source : Bahadur, J., 1996

3.2 BARRIER EFFECT

The barrier theory is the theory of cyclogenesis according to which an invasion of polar air into the zone of dominant westerlies acts as a barrier to these winds and gives rise to a depression on the side of the invading air downwind from westerlies, i.e. to the east of the invading air.

The effects that an orographic barrier produces on air motion depend, first, on the dimensional characteristics of the barrier, its height, length, width, and the spacing between successive ridges – and, secondly, on the properties of the airflow itself – the wind direction relative to the barrier, the vertical profiles of winds and the stability of air (Barry, R.G., 1981). Each of the three dimensions of a mountain barrier interacts with a particular atmospheric scale parameter. Hence, the vertical dimension of the mountain should be compared with the atmospheric depth, as measured by the 'density scale height' (about 8.5 km – thickness of an hypothetical incompressible atmosphere of constant density)The length of the range, in relation to the wind component perpendicular to it, greatly influence the degree of airflow perturbation. An air-stream will separate around an isolated mountain, whereas a range of several hundred kilometers long may cause blocking of the flow, forced uplift, flow deflection, or some combination of these.

Barrier width interacts with five different atmospheric length scales (Smith,R.B., 1979):

(i) The thickness of the boundary layer (~ 300 m)
(ii) The distance the air travels downward during a buoyancy oscillation (about 1 km)
(iii) The downward travel during the condensation and precipitation (about 1h)
(iv) The downward travel during one rotation of the earth (about10^3 km)
(v) The earth's radius (about 6000 km), which determines the magnitude of the effect of the earth's curvature on the large scale flow.

The barrier effect of the Himalayan ranges, limits the northward movement of summer monsoon air and of the Tibetan plateau on the southward movement of cold air from the shallow Siberian high in winter. The details have not so far been investigated for these major effects which influence a large part of the land mass. The forcing to the wind flow provided by the high Tibetan plateau, modifications made by the criss-cross mountain ranges and those of individual peaks has hardly been investigated.

3.3 GEOGRAPHICAL FACTORS

Altitude, latitude, and longitude of a locality are important geographical factors affecting atmospheric conditions.

3.3.1 Altitudinal Effects

The altitude of a place is the height generally expressed in meters above the mean sea level (asl).The effect of altitude on climatic elements is of primary importance. Atmospheric state variables of pressure, density and vapour pressure are reduced with increasing altitude. The high altitude environment is one of severe stress for human beings due to oxygen deficiency affecting physiological factors and responses. When the body cannot maintain its core temperature (37°C), the condition of hypothermia results. Unconsciousness sets in when the core temperature falls to about 30°C and that heart generally ceases at 26°C. Recurring, or prolonged, exposure to cold, damp conditions commonly results in swelling and irritation of parts of the skin on the hand and feet.

The altitude also affects the variation of radiation components, air temperature wind velocity and the energy and moisture budgets.

3.3.2 Latitudinal Effects

Latitude is the distance north or south of the equator measured in degrees. The influence of latitude on the climate (Barry, R.G.,1981) is shown by the following:

(i) Solar and net radiation and temperature broadly decrease with increasing latitude and, as a result, the elevations of the tree line and of the snow line decrease pole-wards.

(ii) It is apparent in the relative importance of seasonal and diurnal climatic rhythms. This is determined by the seasonal trend in the daily sun path at different latitudes. Seasonal changes of solar radiation, day-length and temperature are basically small in low latitudes, whereas the diurnal amplitude of temperature, is relatively large.

(iii) In mountain valleys or on high plateaus, the range of mean daily temperature is considerably larger than on mountain summits due to less mixing of the air with that of free atmosphere.

(iv) Latitudinal differences in mountain climate arise due to characteristics of the global atmospheric circulation. Tropical mountains are within the easterly trade wind regime, mid-latitude mountains are within the westerlies. The tropical easterlies decrease with height, whereas the westerlies increase steadily. Associated with these

differences in the global wind belts, precipitation systems are primarily convective and small-scale in low latitudes, but cyclonic and generally large-scale in middle and higher latitudes.

3.3.3 Longitudinal Effects

Longitude is the distance east or west measured in degrees, from a meridian (circle round the globe, passing through a given place and the north and south poles) especially that of Greenwich, in London. It is just to specify the geographical location unlike latitude (distance north or south of the equator measured in degrees) which is actively associated with air circulations due to energy exchanges. In terms of distance, one degree of longitude has the same length only at the equator (about 111 km). Elsewhere, the length decreases until it becomes zero at the poles where all the meridians meet.

3.4 MICRO-CLIMATES

Microclimate is the fine structure of the air space which extends from the very surface of the earth to a length where the effects of the immediate character of the underlying surface no longer can be distinguished from the general local climate. The micrometeorology is the study of small-scale meteorological conditions, generally involving refined measurements close to the earth's surface over short periods of time and over small areas. The study of a microclimate involves the study of profiles of temperature, moisture and wind in the lower stratum of air (boundary layer), the effect of vegetation and shelterbelts, and the modifying effect of towns and buildings. The boundary layer (BL) is a region close to the earth's surface of the variable depth and stability characteristics with few observations. There seems to be definite time scale of these variations, which may or may not be assoctiated with the synoptic scale changes in the region. The BL is indeed a buffer zone where heat ,moisture and momentum are fed into it (or exhausted from it) by the undulating land or ocean surface. For various reasons not clearly known,the BL breaks down periodically and its contents (fluxes) are distributed through a much greater depth of the atmosphere where it can effect synoptic changes on a much larger scale .However ,the determination of fluxes over the sea can be much different than that over the land since the sea has a larger capacity or storage of heat and moisture with very gradual

changes in temperature (scale of the order of 15 to 30 days), the surface fluxes have to be determined primarily by the SST, the low level wind speed, the temperature and humidity of the air above the surface over which has a limited capacity of storage,the situation is different. The fluxes are determined by external factors like incoming solar radiation, rainfall etc and the BL adjusts its own structure according to these inputs. This is the conventional view in modeling detailed structure of BL is not considered necessary over land and the bulk layer approach came into vogue.

Due to large altitudinal range of Himalayan mountains, various microclimatic regions in different altitude regions ranging from tropical (300-900 m), warm temperate (900-1800m),cool temperate(1800-2400m), cold (2400-3000 m), Alpine (3000-4800 m) and perpetually frozen (>4800m).

As a general guide, the altitude-dependent distribution of temperature in the Himalaya and the Karakoram may be characterized (Kalvoda, J, 1992) by Table 3.4.1.

TABLE 3.4.1

Altitude Dependent Distribution of Temperature for Warmest Months for Himalaya and Karakoram*

Zone	*Altitude Range*	*Average temperature in July or August*
Tropical (foreland of the Eastern Himalayas)	Upto 600 m	Above 35°C
Sub tropical	Below 1200 m	30-35°C
Moderately warm	1200-1900 m	25-30°C
Moderately cold	2500-3800 m	15-20°C
Cold	3800-5500 m	5-15°C
Very Cold	Over 5500 m	0-5°C

*Source: Kalvoda, J., 1992.

Regionally, these zones vary somewhat with the boundaries measuring from west to east, as well as from south to north. The vegetation altitude zones are determined by the distribution of the temperature and precipitation throughout the profile. The orientation of the exposed slopes, the relative humidity and the local wind

direction plays a major role in this respect. The extreme variations in regional conditions are illustrated for example by the Cherrapunji valley in Assam where in 1861, 22,900 mm of precipitation was measured though the long-term annual rainfall amounts to no more than 11,600 mm of which 2900 mm falls in June and 2700 mm in July.

The recent snow line occurs on the northern slopes of the Great Himalaya at altitudes ranging from 5200 to 5900 m, rising from west to east; the southern slope, it lies between 4700 and 5400 m. In Kashmir, the valley glaciers descend to as low as 3000-3700; in Kumaon to 3900-4000 m; in Nepal to 4200-4400 m and in Bhutan to 4500-4600 m asl. On the northern slopes of the Himalaya, the lower limit of glaciation is, on an average 700-800 m higher. Regionally, the snow and tree lines show the variation listed in Table 3.4.2. (Troll, C, 1967 and Others).

TABLE 3.4.2

Altitude Ranges of Snowline and Tree Line in Himalaya and Karakoram*

Mountain Region	*Altitude of the snow line (m)* southern slopes (m)	northern slopes	*Altitude of the tree 'line on*
Western Karakoram	4600	5800	3600
Eastern Karakoram	4700	5900	3700
Western Himalaya	4700	5400	3800
Central Himalaya	5100	5800	4000-4100
Eastern Himalaya	5000	5700	4100-4200

*Source: Troll, C., 1967

The maximum relative retreat of snowline during the Pleistocene is estimated to range from 2000-2600 m in the Himalayan region.

3.5 THERMAL EFFECTS

Thermal updraught is produced locally above a surface warmer than its neighbourhood. Thermal belts are several horizontal belts of vegetation type found in mountainous terrain, as a result of vertical temperature variations, e.g. frostless zone, timber line etc. Thermal efficiency is the climatic element in Thornthwaites' classification of

climates corresponding to the effectiveness of precipitation. It expresses the degree to which the temperature of a place favours plant growth, and ranges from zero on the polar limit of the tundra to a maximum in the tropics.

Thermal patterns of the topography also give rise to characteristic systems of air motion, especially when the regional pressure gradients are weak. The primary forcing agents are elevational differences in *potential temperature* (temperature which an air parcel would have if brought dry diabatically to a pressure of 1000 hPa.) causing vertical motion, and differential heating / cooling along slopes which may set up air circulations with horizontal and vertical components. In the deep valleys of Himalayan ranges such systems are sufficiently frequent and pronounced (Barry, R.G.,1981) in their effects as to create distinctive and semi-permanent topo-climatic patterns.

Thermally driven wind systems include land-sea breezes, as well as the more complex mountain-valley winds. The basic dynamical processes that are involved are (i) an *antiriptic wind* component directed toward low pressure, when the Coriolis effect is small and (ii) a *gravity wind* component directed downslope (*katabatic wind*). Downslope movement of cold air at night is referred to as katabatic flow and upslope movement during day is termed *anabatic flow.*

3.6 DYNAMICAL EFFECTS

Atmospheric dynamics in the study of atmospheric motions including their time variations, which are involved in weather phenomena, on all scales, by means of the principle of theomo-dynamics and fluid mechanics. Dynamic stability (or hydrodynamic stability) is the property of a steady state of the atmosphere, or of a wave of disturbance of the atmosphere, which is not characterized by dynamic instability.

The effects of topography on air motion operate over a wide range of scales and produce an hierarchy of circulation systems through the mechanism of dynamic and thermal factors Three major types of dynamic processes are :

(i) Extensive mountain ranges set up planetary – scale wave motion through large scale rotational effects.
(ii) Mountains give rise to modifications of synoptic-scale weather systems, especially fronts.
(iii) Topography on all scales, introduces wave motion through local gravitational effects.

3.7 SEASONAL ASPECTS

Season is one of the divisions of the year according to the type of weather. Because of the inclined position of the earth's axis (23.5°),mid-latitudes have four well defined seasons – *spring, summer, autumn* and *winter,* while the north and south poles have six months of daylight followed by six months of darkness each year in the region north of 66.5°N (Arctic circle) and south of 66.5°S (Antarctic circle).

There are four principal seasons in India (Monsoon type of climate region)

(i) Winter (Dec-_Feb) or NE-monsoon
(ii) Hot (Mar-May) or Pre-monsoon
(iii) Summer (Jun-Sept) SW-monsoon
(iv) Transition (Oct-Nov) or Post monsoon

For the free atmosphere, the Tibetan Plateau plays an important role in seasonal circulations (Gao You-xi et.al, 1981).In summer (and during the day time) the heating effect resulting from the intensive solar radiation over the Plateau, causes the atmosphere of the mid-troposphere to assume a state of high temperature, low pressure, high humidity, weak breezes, instability and of being abundant in convective clouds, thunderstorms and hailstorms as low pressure vortices, shear lines, and a strong thermodynamic boundary layer prevail. The summer monsoon thermal low over the Plateau is big and strong, the plateau monsoon and its vertical circulation during the summer season prevail, and the plateau experiences its rainy season.

During winter (especially at night), the plateau functions as a cold source or weak heat source, and the atmosphere over the plateau is in a state of low temperatures, high pressure, low humidity, and strong wind. Although the air is unstable and convective clouds are still the principal cloud system, there are no thunderstorms or hailstorms, the thermodynamic layer is weak and thin, the cold high of the plateau monsoon prevails, the winter monsoon and Hadley cell (north-south orientation) are well developed, and the plateau is then in its dry and windy season. During the transition seasons, cold-and-heat source configuration changes rapidly. The plateau is very probably the motivating region that leads to the seasonal long-wave adjustments of the atmospheric circulation.

3.8 MONSOON

The name monsoon is from Arabic word *'Mausim'* which was coined by seafaring traders to describe a system of alternating winds from the Arabian sea and the Indian ocean (Das, P.K. 1984). It is described as the most dramatic of all weather events; appears to be linked to weather and climate in other parts of the globe; complex due to great variations from place to place, year to year; difficult to predict but is intrinsically interesting.

The Indian subcontinent is an excellent example of the monsoon at climate regime. Over this region, sea level pressure and hence the surface winds undergo complete reversal from January to July. For the first six months of the year (January to June), winds blow from northeast while the next six months (July to December), the winds start blowing from southwest.

During winter, high pressure develops over land and low over seas. Dry and cold air of land origin of northerly latitudes flows in North-Easterly direction over sea regions. This is called the Winter or North-East Monsoon. By the end of summer, low pressure is set up over landmass of north India and high shifts to the seas. Now, the flow of warm and moist air of ocean origin occurs from seas to land on the path of winter monsoon, but in opposite direction. Numerical experiments suggest that if the Himalayas were not there, the change over from westerlies to easterlies would be much more gradual. Monsoon is the important source of rainfall. It brings rain in four phases and covers the whole country as indicated by the Table 3.8.1 including the Himalayan region.

TABLE 3.8.1

Four Phases of the Monsoon in India*

Rainfall season	*Duration*	*Percentage of annual rainfall*	*States covered*
North-East monsoon	Jan-Feb	2.6	Bihar, M.P., Punjab, Rajasthan, U.P.
Pre-monsoon	March-May	10.4	Assam, Bihar, Parts of Kerala, Orissa, Tamil-nadu and West Bengal
South-West monsoon	June-Sept	73.4	Almost whole of the country

(Contd.)

(Table 3.8.1 Contd.)

Rainfall season	*Duration*	*Percentage of annual rainfall*	*States covered*
Post monsoon	Oct-Dec	13.3	Assam, Coastal Andhra Pradesh, Kerala, Orissa, Tamilnadu, West Bengal

* Source: Rao,V.R et.al.,1993

For a more comprehensive coverage of monsoons, a reference may be made to WMO Monograph (Das, P.K.,1984) or (Fein, J.S. and Stephens, P.A., 1987). The former publication deals with the scientific aspects, while the later includes many perspectives, including :

- the influence of the monsoon on traditional culture.
- an economic analysis of the value of weather and climate data in developing countries
- the evolution of the concept of the monsoon as a weather and climate system from the early mariners to today's scientists.
- a most thorough treatment on monsoon variability on paleo-climate time scales.
- an in-depth look at topographical influences on monsoons, ocean monsoon in directions, and interactions of monsoons with other global weather and climate events.
- the latest information on the tools being used to predict the variability of monsoon.

It also examines an intriguing hypothesis which states that it is inherently easier to predict the average behaviour of the monsoon on monthly and seasonal time scales than to forecast monsoon weather patterns a few days in advance – a topic of great concern to farmers, atmospheric scientists and policy makers.

3.9 PRECIPITATION DISTRIBUTION

The precipitation distribution in the Himalayan region is highly variable and complex. In general, there are heavy and prolonged precipitation events in the eastern region, rapidly decreasing in both intensity and duration as the monsoon advances westwards. It is observed that the monsoon currents passing over the eastern Himalayas reach heights of 6000m.

Over a period of time after the uplift of the Himalayas, the average annual precipitation in NW- region is about 80% in winter (mostly snow over about 3000m) and 20% in summer seasons, creating cold arid to semiarid conditions. This is just the opposite of Eastern and NE regions where the winter precipitation is about 20% and the summer contributions touch up to 80% or more, creating a humid and per-humid environment.

In general, there is an increase in precipitation with altitude. The annual orographic increase in precipitation may range from less than 10mm per 100m to over 300mm per 100m rise of elevation, depending on the environmental conditions of extreme continentality to maritime (Upadhyay, D.S. and Bahadur J., 1982) The orographic precipitation is greater by a factor of 2 to 3 on windward slopes as compared to leeward slopes. In extratropical regions, the effect is enhanced during winter months as compared to summer months. This is, however, not favoured in the Himalayan region. We observe both increase or decrease of precipitation with the increase of altitude during summer or winter as shown by the following results of precipitation over different regions/altitude ranges of the Himalayan region (Bahadur, J, 1993)

TABLE 3.9.1

Orographic Increase in Precipitation (mm per 100m) in Himalayan Region from West to East*

S. No	*Region*	*Annual*	*Summer (May-Sept.)*	*Winter (Oct. –April)*
1.	Jammu & Kashmir	-37	-30	-7
2.	Punjab + Himachal Pradesh	+72	+3	+69
3.	Himachal Pradesh	-13	-60	+47
4.	Uttaranchal	+41	+35	6
5.	Sikkim	-33	-32	-1
6.	Eastern Nepal Sikkim – Southern Tibet	-87	-	-

*Source: Bahadur, J. (1993)

TABLE 3.9.2

Orographic Increase in Precipitation (mm per 100m) in Different Altitude Ranges in the Himalayas*

S. No	*Altitude Ranges*	*Annual (May-Sept.)*	*Summer (Oct. – April)*	*Winter*
1.	Less than 1000m	+111	+76	+35
2.	1000-2000m	+34	+39	-5
3.	2000-3000m	-13	-58	+45
4.	3000 and above	+174	+179	-5

* Source: Bahadur, J., (1993)

3.10 HYDROMETEORS AND HYDROMETEOROLOGY

An aggregation of particles of water or ice in the atmosphere are known as *hydrometeors*. This includes all precipitation but excludes cloud forms, non-aqueous meteors such as litho-meteors (smoke, dust, sand); photo-meteors (halos, coronas, rainbows) and electro-meteors (northern heights, lightning and thunder). The most common hydrometeors (WMO, 1956) are listed in Table 3.10.1.

TABLE 3.10.1

Common Hydrometeors*

Rain	Precipitation of liquid water particles, usually in the forms of drops of more than 0.5mm.
Drizzle	Fairly uniform precipitation compared exclusively of fine drops of water (diameter < 0.5mm)
Freezing rainor Drizzle	Rain or drizzle, the drops of which freeze on impact.
Snow	Precipitation of ice crystals, most of which are branched.
Snow Pellets	Precipitation of which are opaque spherical grains of ice with diameter of about 2 to 5 mm.
Snow Grains	Precipitation of very small, fairly flat, white and opaque grains of ice, their diameter in generally less than 1mm.
Ice Pellets	Precipitation of transparent or translucent spherical pellets of ice which have a diameter of 5mm or less.
Hail	Precipitation of small balls or pieces of ice with diameter ranging from 5 to 50mm

(Contd.)

(Table 3.10.1 Contd.)

Ice Prisms	A fall of unbranched ice crystals the form of needles, columns or plates, often so tiny that they seem to be suspended in the air.
Fog	A suspension of very small water droplets in the air generally reducing the horizontal visibility at the earth's surface to less than 1 km.
Ice Fog	A suspension of numerous minute ice crystals in the air, reducing the visibility at the earth's surface.
Mist	A suspension in the air of microscopic water droplets reducing the visibility at the earth's surface.
Drifting Snow & Blowing Snow	An ensemble of snow particles raised by the wind.
Spray	An ensemble of water droplets formed by the wind from the surface of an extensive body of water.
Dew	This is a deposit of water drops on objects on the ground.
White Dew	This is a deposit of white frozen dew drops
Hoar frost	This is a deposit of ice having a crystalline appearance ,which generally assumes the form of scales, needles; feathers or fans
Rime	A deposit of ice, composed of grains more or less saturated by trapped air.
Glaze(clear ice)	A generally homogeneous and transparent deposit of ice formed by the freezing of super cooled drizzle droplets or raindrops on objects the surface temperature of which is below or slightly above 0° C .
Spout	A phenomenon consisting of an often violent whirlwind revealed by the presence of cloud column or inverted cloud cone (funnel cloud protruding from the base of a cumulo-nimbus.

* Source: WMO, 1956

Hydrometeorology is a study of the occurrence, movement and changes in the state of water in the atmosphere. The term is also used in a more restricted sense, especially by Hydrologists to mean the study of the exchange of water between the atmosphere and the continents. This includes the process of precipitation and direct condensation, and of evaporation and transpiration from natural surfaces. Considerable emphasis is placed on the statistics of precipitation as a function of area and time for given locations or geographical regions (Bruce, J.P. and Clark, R.A.1966). Another definition is a part of meteorology, which is of direct concern to

hydrological problems, particularly flood control, hydroelectric power development, irrigation scheduling and other aspects connected with water resources management (Wiesner, C.J.1970). Thus hydrometeorology is an important discipline for reconstruction and development of natural environments.

Water occurs in the atmosphere primarily in vapour or gaseous form. The average amount of vapour tends to decrease with increasing elevation and latitudes and also varies strongly with season and the type of ground surface. Precipitable water, the mass of vapour per unit area contained in a column of air extending from the surface of the earth to the outer extremity of the atmosphere, varies from almost zero in continental Arctic air to about 6 g/cm^2 in very humid tropical air. Its average value over Northern Hemisphere varies from around 2 g/cm^2 in January and February to around 3.7 g/cm^2 in July. Its average value is around 2.8g/cm^2, an amount equivalent to a column of liquid water slightly greater than 2.5 cm in depth. Close to 50% of this water vapour is contained in atmosphere's first 1.5 km and about 80% is found in the lowest 3 kms.

Although a trivial portion of the water of the globe is found in the atmosphere at any one instant, the rate of exchange of water between atmosphere and the continents and oceans is high. Evaporation from the ocean surface and evaporation and transpiration from the land are the sources of water vapour for the atmosphere. The water vapour is removed from the atmosphere by condensation and subsequent precipitation in the form of rain, snow, sleet, and so on. The amount of water vapour removed by direct condensation at the earth's surface (dew) is relatively small.

The ice phase originates in natural clouds either by the freezing of liquid droplets or by condensation on aerosol particles at temperatures below 0°C. However, small droplets of pure water do not readily freeze and the liquid phase may exist in a metastable state down to –40°C, below this temperature, freezing occurs spontaneously by homogeneous nucleation. In presence of foreign particles called ice nuclei, the droplets freeze at comparatively higher temperatures.

Once ice phase has been initiated in a cloud, the embryos of ice may continue to grow into snow or ice crystals by diffusion of water vapour. Laboratory experiments have shown that the shape, or habit which a snow crystal assumes as it grows from the vapour phase is determined mainly by the temperature at which the growth takes place.

There are four basic variations of snow crystal habits with temperature from 0° C to –3° C and from –8° C to –25° C, the growth is essentially plate-like and from –3° C to –6° C and below –25° C, the growth is essentially prism-like.The growth of ice particles in clouds is a powerful mechanism for formation of precipitation and it is now believed that most of the precipitation originates as snow crystals high up in the atmosphere.

Hydrometeorology is particularly concerned with the measurement and analysis of precipitation data. Since 1950 increasing attention has been paid to the use of radar in estimating precipitation. By relating the intensity of a radar echo to the rate of precipitation, it has been possible to obtain a vast amount of detailed information concerning the structure and the areal distribution of storms. Deficiencies in the observational network over the ocean and over the more sparsely inhabited land areas of the earth are now being bridged through the use of meteorological satellite observations. Progress in the 1970's towards development of methods for the estimating rainfall amounts from satellite observations of cloud type and distribution is of particular significance to hydrometeorology.

3.11 PALEOCLIMATOLOGICAL INVESTIGATIONS

Paleoclimatology is the study of paleoclimes i.e. climates of prehistoric period whose main characteristics may be inferred, for example from geological and paleobiological (fossil) evidence (Table 3.11.1).

Himalayan regions possess a diversity of natural archives and historical records from which paleoclimatic records can be developed (e.g. lake sediments, loess, tree rings, ice cores, glacier fluctuations, geomorphological features). Despite this potential, relatively little is known concerning climatic changes in the region over time scales ranging from centuries to hundreds of thousands of years. This is especially significant given the critical role and the importance of the Asian summer monsoon in providing life sustaining rains to a considerable portion of the world's population.

A competent overview of Quaternary Paleobotany / Palynology in the Himalaya is given by Vishnu – Mittre. This overview appraises critically on the Quaternary paleobotany / palynology in the Himalaya (Vishnu – Mittre, 1984) during the last hundred years. The fluctuations in cool and temperate vegetation and climate during the early

Quaternary (Lower Karewas), the aspects of vegetational development during the last glaciation and during the present interglacial period impart a glimpse of the changing patterns of vegetation the intensification of research on the comparative data base, together with increased indigenous ecological insight and the sophistication in methodology. This bring out invaluable information on biogeographical, geological and archeological interests. The history of lake basins and fluctuations in hydrochemistry should be built up through the study of diatoms in conjunction with pollen and spores.

TABLE 3.11.1

Characteristics of Natural Archives*

Archives	*Temporal Precision*	*Extent (Yrs)*	*Derived Parameters*
Tree rings	Yr/season	10^4	T,H,C_A, B,V,M, S
Lake sediments	Yr	10^1-10^6	T,B,M
Ice cores	Yr	10^3-10^5	T,H,C_AB,V,M,S
Coral deposits	Yr	10^5	T,C_w, L,
Loess	10 Yr	10^6	H,C_S, B, M
Ocean Cores	100 Yr	10^7	T, C_w, B, M
Pollens	1000 Yr	10^5	T, H, B
Paleosoils	100 Yr	10^5	T,H,C_s,V
Sedimentary rock	2 Yr	10^7	H,C_s,V, M,L
Historical records	Day/hr	10^3	T, H B,V,M,L,S

where, T – temperature
H – humidity or precipitation
C – chemical composition of the air (a), water (w), or soils (s)
V – volcanic eruptions
B – information on biomass as in pollen samples
M – geomagnetic field
L – sea level
S – solar activity

* Source : IGBP, 1988.

The studies on the evolution of Quaternary floristics should not overlook the historical perspective i.e. its evolution from the Miocene / Pliocene flora. The recognition of a transitional stage in the evolution of flora are highly imperative for demarcating the Neogene / Quaternary boundary on botanical grounds. A few names for various stages (vegetational / climatic phases) during the Quaternary have

been proposed after the type sites in keeping with the *Code of Stratigraphical Nomenclature* for their use in bio- and chronostratigraphy. In addition, it emphasizes the importance of indigenous ecological insight on ecological problems and biographical riddles in the diversity of floristics of the Himalaya. It also helps to determine the rate and extent to which the forests in the Himalaya have been adversely affected by progressive increase in land use and by the progressive and selective exploitation of forest constituents.

Past Global Changes (PAGES) under the International Geosphere-Biosphere Programme (IGBP) has taken an initiative on Himalayan Inter-disciplinary Paleo-climate Project (HIPP), launched in 1994. It's the primary goal is to develop an integrated, multidisciplinary international approach towards collection, calibration and interpretation of high resolution paleo-climatic records from several natural archives (e.g. lake sediments, loess tree rings, ice cores, glacier fluctuations, geomorphic features peat deposits etc.) over the broad region defined by the Himalayas and the Tibetan Plateau. This will provide background knowledge necessary to identify temporal and spatial variations in the linkages between various climate systems in Asia and to determine the hierarchy of forces controlling climate change in this region. Specific scientific questions that can be addressed using this multi-proxy, high resolution reconstruction of climate over the Himalayan – Tibetan Plateau regions are outlined below :

(i) What was the response of the SW –summer monsoon and westerly jet stream circulation to past decadal to century scale climatic fluctuations such as the Little Ice Age (LIA), the Medieval Warm Period, the Climatic Optimum and the Younger Dryas of Europe ? Specifically, how did the inter-annual variability of SW monsoon change during these episodes, if it changed at all ?

(ii) How does the relationship between the SW-*Monsoon* and *El Nino/Southern Oscillation (ENSO) change over time?* Several studies have identified strong links between variations in the monsoon intensity and ENSO events over the past 150 years, warm ENSO events correlate with weaker than normal monsoon. Records of past changes in the behaviour of the SW – and plateau monsoons will expand the geographical extent of ENSO – related

paleoclimatic records, thereby providing valuable input for evaluating the spatial consistency of large scale climate patterns related to ENSO over the past several hundred years.

(iii) What are the physical processes which control the interannual variability of the SW-monsoon? Are the forcing functions predominantly external (e.g. solar cycles, volcanism, anthropogenic activities) or internal (e.g. Eurasian snow cover, cloud feedbacks, sea surface temperature, ENSO events)?

(iv) How extensive, in time and space, were abrupt changes in the strength of the SW-monsoon, how do they relate to other abrupt changes observed around the world, and how are they forced ? What is the probability that abrupt changes from one climatic state to another might occur in the future?

(v) How have biogeochemical cycling and vegetational patterns changed in central Asia in comparison to changes in climate? Comparison of paleo records from ice cores, tree rings and lake sediments developed over a wide geographic region will provide the framework to investigate variations in the dynamics of the terrestrial biosphere and biogeochemical cycling in the high lands of Central Asia. In addition, ice-core records may also provide information on variations in marine productivity.

(vi) How has the trans-equatorial heat flux associated with SW monsoon changed over time ? SW-monsoon circulation is driven predominantly by the transfer of solar energy via cycles of evaporation and condensation, from the tropical Indian Ocean northwards over the Indian subcontinent. Multivariate, high resolution records of the SW-monsoon and of solar variability can be used as a proxy indicator of variations in the energy flux associated with summer monsoon circulation.

(vii) How will climate in Southwest Asia change in future? Answers to questions (i) to (vii) will provide valuable information, constraints and basic boundary conditions (e.g., synoptic weather patterns, precipitation patterns, temperature fluctuations) for paleoclimatic model simulation. These data will therefore serve to improve and

test climate models which attempt to predict future climate change. A coordinated effort to collect multi-proxy paleo-climate records, and to understand the significant tele-connections and forcing, will improve the reliability of models which forecast future ecological and climatic change.

In Kashmir valley (northwestern Himalayas), we have Karewa formations (inter-montane valley fill comprising of unconsolidated fluvo-lacustrine sediments of more than a km thickness). These sediments were investigated (Agarwal, D.P.et al., 1989) under an inter-disciplinary multi-agency project using a variety of dating techniques and other analyses to decipher the climate change. A variety of proxy climate data from a long continental record is made available from northern most South Asia, giving litho-stratigraphic and chronologic framework of the sediment profile and proxy data based on flora, fauna, stable isotopes, pedology, mineral magnetics and sedimentology. The climatic events are put in an absolute time-frame for comparison with the global climatic trends based on ^{14}C, thermoluminescence (TL), paleomagnetic and fission track chronology.

The results show that up to 3.8 m yr (B.P.)., the climate seems to be warm temperate, becoming cooler towards the top of the profile. From 3.7 to 2.6 m yr (B.P.), there is a transition from subtropical type of climate to a cool temperate type. With some variation in precipitation, cool temperate until c 2.2 m yr. Between 0.6 and 0.3 m yr, there are three relatively long cold periods. The evidence is based on pollen but is supported by stable isotopic and faunal data. The loess deposits covers the last 200 k yr. Field characters of pedogenic development, geochemical and magnetic susceptibility variations indicate 10 palaeosols during this period, out of which 3 palaeosols show greater weathering and may therefore reflect warmer/humid conditions compared to the others. For the last 17 k yr, there are a few pollen profiles available now. Between 10,000 yr B.P. and present, the pollen profile show a cool temperate-warm temperate–cool temperate cycle. What is remarkable is that the warming of the valley is indicated around 17 k yr. It is further confirmed by the soil debris of the palaeosol from Burazhom, derived from C3 type of plants and dated at c.18 kyr. By mid-Holocene, a warming up is evident accompanied by culture pollen which indicates Neolithic occupation

of the valley. In the valley, the human settlements thrived only during periods of climatic ameliorations at c18000 yr B.P., there was an Upper Paleolithic culture at c 5000 yr B.P., Neolithic cultures; and at c 1000 B.P., historical dynasties.

Around 4 m yr(B.P), the Pir Panjal range was further up-thrusted to impound the Himalayan drainage, thus forming a vast lake, the exposed sediments of which are called Karewas. At around 3 myr (B.P), the Pir Panjal range rose to a height where it could block the SW-monsoon from entering the valley and thus converting it from a region of subtropical climate to a temperate one. Since then it has followed a Mediterranean pattern of climate with winter rains. Some time before c 200 kyr, the primaeval lake shrank and shifted to the Himalayan side, exposing Karewas on the SSW. Once these Karewas were exposed, they pervaded a stable land surface for the aeolian deposition of loess. The Jhelum river emerged around 85 kyr and drained the remaining lake also. The newly exposed lake deposits provided land surfaces for the aeolian deposition on the Himalayan flank as well.

Sharma, C and Chauhan, M.S. (1999) have reported on palaeoclimatic inferences from Quaternary palynostratigraphy of the Himalayas. The paleo-vegetation succession and climatic oscillations impressed chiefly from Karewas deposits in Kashmir cover 3.8 myr; in Himachal Pradesh 8000 yrs; in Garhwal Himalaya 6000 yrs; more than 40,000 yrs in Kumaon Himalayas as well as Kathmandu valley (Nepal); 20,000 years in Darjeeling and 2,500 years in Sikkim.

For climatic variability over western Himalayas, the snowfall and temperature for ten stations, widely spread over western Himalaya have been analysed (Pant, G.B. et al., 1999). They do not show any significant long term trend during the past century. The temperature analysis indicates increasing trend in all the seasons except the monsoon, which shows overall decreasing tendency for most of the stations. Tree-ring chronologies of Himalaya conifers can be used to study the long-term fluctuations in climate. The reconstructed summer temperature and precipitation series over the Western Himalaya do not show any significant long term trend during the last two centuries.

Eolian dust deposition at high altitude glaciers in Central Asia (Fig 3.11.1) are likely to provide long-term (10^2 to 10^4 yrs) dust deposition records (Wake C.P. and Mayewski, P.A. 1994) reflecting regional to hemispheric signals. The analysis of concentrations and

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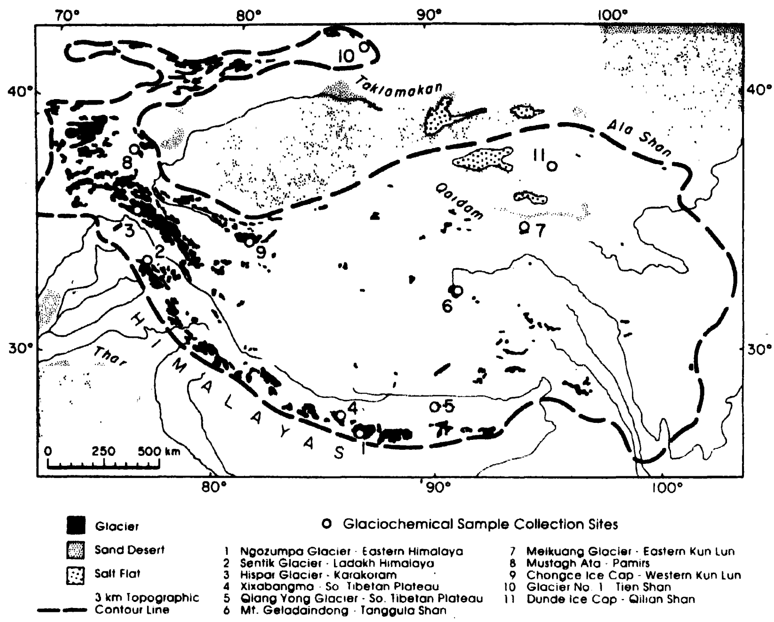


Fig. 3.11.1 Location Map of Glacio-chemical Sample Collection Sites in the Mountains of Central Asia

size distributions of insoluble particles (over 1-22 mm diameter) in snow and ice samples from eight glaciers in Central Asia show four distinctive geographical areas, (i) southern slopes of eastern Himalaya show very low particle concentrations and low annual dust deposition (ii) Karakoram appears to be major sink for particles less than 2mm in diameter which have been transported over long distances with a westerly jet stream (iii) Glaciers in the SE Tibetan Plateau record the influx of dust generated in the arid and semiarid regions to the west (iv) Glaciers on the northern and western margin of the Tibetan Plateau, lie adjacent to vast arid and semi-arid regions of western China and provide dust deposition records, mainly of local significance.

Joint American and Chinese studies on the ice cores from ice caps in Tibet have revealed the records of 1000 years of climate change (Lin, P.N. et al, 1995). The ice cores were collected at an altitude of 6200 m, asl from the Guliya ice cap, located in NW Tibet (with an average annual precipitation of 180 mm/yr) and Dunde ice cap at an altitude of 5325 m, asl from NE-Tibet (with average annual

precipitation of 1400 mm/yr). The reconstructed temperature histories for the ice caps show some centennial-scale similarities, but reveal quite different histories for higher frequency variability over the last millennium. The ice core $d^{18}O$ - histories from Dunde and Guliya are compared with a tree-ring index from western China and dust fall record from eastern China, but they show no consistent relationship. The most prominent similarity between the reconstructed temperature histories for Dunde and Guliya is the marked warming of the last few decades. From the 1000 years perspective provided by these ice-core records, the warming on Dunde is unique in its strength and perspective; however, the warming on Guliya is more recent (since 1985) and not unprecedented. The recent warming over the Tibetan Plateau is evident in the limited meteorological records. The Guliya history contains a major cool phase around 1500 AD, but this does not appear to have extended to east. The warming appears to have begun several decades earlier on the lower-elevation Dunde ice cap (5325 m) and more recently since 1985, on the higher Guliya ice cap (6200 m) to the west. It is worth noting that most of the moisture for the eastern side of plateau is associated with highly convective monsoon rains and the release of latent heat is associated with cumulus – convective precipitation, contributing to atmospheric heating. While on the western side of the plateau, heating is largely due to vertical convection, driven by intense radiational heating and predominant moisture is from Arabian sea.

Ice core records from the Dunde ice cap provide a detailed record of Holocene and Wisconsin-Wurm phases of the last glacial stage (LGS) climate changes in the subtropics (Thompson, L.G. et al, 1989). The records reveal that LGS conditions were apparently colder, wetter, and dustier than the Holocene conditions. The LGS part of the cores is characterized by more negative $d^{18}O$ ratios, increased dust content, decreased soluble aerosol concentrations and reduced ice crystal sizes than the Holocene period. These changes occurred rapidly about 10,000 years ago. In addition, the last 60 years were apparently one of the warmest periods in the entire record, equal to the levels of the Holocene maximum between 6000 and 8000 years ago. The LGS-Holocene transition at 10,750 years ago using the dated horizon at 117 m depth. Although these results are rough estimates because of pronounced variations in accumulation rate, and the shape of the ice sheet. These estimates suggest that the record in potentially more than 100,000 years old.

While discussing the role of monsoons in Himalayan glaciation (Benn, D.I and Owen, L.A, 1998), it is argued that the long-term variability in the intensity and/or duration of the South Asian summer monsoon is correlated with the 23,000, 41,000 and 100,000 years orbital cycles. The precession and obliquity cycles determine the timing of insolation maxima and magnitude of the thermal and pressure gradients between the Indian Ocean and the South Asian landmass which drive the summer monsoon. A strong influence is also exerted by the 100,000 year eccentricity cycle, probably due to the effects of global cooling on continental albedo and the effects of the large mid-latitude ice sheets on atmospheric circulation. At the time of last glacial stage (c 30 – 11 ka BP), the South Asian Monsoon was less intense and / or had a shorter duration than today. Over Kashmir, Ladakh and the Tibetan Plateau, conditions appear to have been windy and humid, probably as the result of enhanced westerly circulation. The climate was variable at this time, with millennial–scale fluctuations in temperature and humidity. On the loess plateau, windy, continental conditions predominated. Around the beginning of the Holocene, the South Asian Monsoon increased in intensity, and there was a decrease in wind intensity on the northern Tibetan Plateau. At the same time, the Plateau became more arid. During the Holocene, climatic fluctuations in the northern Tibetan Plateau and regions to the south appear to have been out of phase.

3.12 CLIMATE CHANGE INVESTIGATIONS

In the most general sense, the term 'climate change' encompasses all forms of climatic inconsistency (i.e. any differences between long-term statistics of all the meteorological elements, calculated for different periods but relating to the same area regardless of their statistical factors as changes in solar emission, long period changes in the earth's orbital elements (eccentricity, obliquity of the ecliptic precession of the equinoxes), natural internal processes of the climate system or anthropogenic forcing (e.g. increasing atmospheric concentration of carbon dioxide or other greenhouse gases). The term 'climate change' is often used in a more restricted sense to denote significant change (i.e. a change having important economic, environmental and social effects) in the mean values of a meteorological element (in particular temperature or amount of precipitation) in the course of certain period of time, where the means are taken over period of a decade or longer.

Greenhouse gases (Carbon-dioxide, Methane, Nitrous oxide , Chlorofluoro carbons – CFCs and Tropospheric Ozone) cause infrared radiation to be retained on the atmosphere , warming the earth's surface and the lower part of the atmosphere. Water vapour is by far the most important natural greenhouse gas. The second most important natural greenhouse gas is carbon dioxide which is released by volcanic eruptions. The man-made carbon dioxide is released by burning the fossil fuels and the destruction of forests. Methane (CH_4), Nitrous oxide (N_2O), Chloro-fluorocarbons (CFCs) and Tropospheric Ozone are other greenhouse gases (Table 3.12.1).

TABLE 3.12.1

Green House Gases*

Characteristics	*Carbon dioxide* CO_2	*Methane* CH_4	*Nitrous Oxide* N_2O	*Chloro-fluoro Carbons* *CFCs*	*Topospheric Ozone* O_3
Lifetime in atmosphere (except for CO_2 in atmosphere-ocean biota-system)	50-200 yrs	7-10 yrs	150 yrs	75 yrs CFC-11 110 ys-CFC-12	Hours or days
Percentage contribution to greenhouse effect 1950-1985	53	13	6 to 7	20	Variable, about 8
Pre-industrial concentrations	275 ppmv*	0.7 ppmv	228 ppbv+	zero	15 ppbv
1990 concentration (estimated)	354 ppmv	1.7 ppmv	310 ppbv	-26 ppbv CFC-11.44 ppbv CFC-12	35 ppbv
Annual rate of growth in concentration in 1980s	0.5%	0.9%	0.25%	45%	1%
Relative cumulative effect of 1990 manmade emissions over the next 100 years	61%	15%	4%	11.5%	8.5%

(Contd.)

(Table 3.12.1 Contd.)

Charac-teristics	*Carbon dioxide* CO_2	*Methane* CH_4	*Nitrous Oxide* N_2O	*Chloro-fluoro Carbons* CFCs	*Topospheric Ozone* O_3
Major sources	Fossil fuel burning defores-tation and land use changes	Swamps, rice paddies, ruminants, fossil fuel extraction	Fossil fuels and biomass burning, fertilizers, land-use changes	Man-made chemicals used as solvents spray can propellants, making of foam and refrigeration	Formed from vehicle exhausts and other industrial pollutants in sun-shine

where ppmv = parts per million by volume; +1ppbv = parts per billion by volume

* Source : Climate change : Meeting the challenge – Commonwealth Secretariat 1989 and Report of IPCC Working Group 1, 1990.

The life time of these gases in the atmosphere varies from a few hours or weeks for low level ozone to more than 100 years for CFC-12. The carbon dioxide can have a combined life time of 200 years in the biosphere and the upper ocean surface. As these man-made changes in the planetary atmosphere are occurring very fast due to human activities, there is need to have reduction in the releases of these greenhouse gases by appropriate modification in strategies of industrial production, reforestation and changing agricultural practices. Energy conservation and efficiency along with the phase out of CFC production are the priority for national and international action.

There is a scientific consensus that global warming of the order of 1 to 2°C will occur by 2030 AD. By 2030 AD, the earth is likely to be warmer than at any time in the past. 120,000 years. Extreme weather events could become more common. Tropical storms could increase in intensity. A best guess is that sea level will rise by 17-26 cm by 2030 followed by continued increase thereafter.

Some of the implications for the Indian sub-continent for the climatic changes greenhouse gas emissions, future climate and response strategies are reviewed by Rao, P.G. et al., (1994) with the following conclusions :

(i) India's mean surface air temperature has increased by about 0.4°C during the past century, with variability in space and time. The increase is mainly due to an increasing trend in

mean maximum temperature, contrary to the characteristics observed for the northern hemisphere as a whole.

(ii) Monsoon rainfall does not show any significant systematic trend, although some decadal variations are conspicuous

(iii) On any average, there has been a rise in sea levels around the country of about 2.5 mm/yr over recent decades.

(iv) Carbon emissions from the energy sector amount to 71 MT/yr, equivalent to all other sectors combined. For the land-use data, it appears that a marginal sequestration of 5.25 million tonnes of carbon occurred during the year 1986.

(v) Methane emissions from rice and livestock is estimated at 17.4 and 12.8 Tg/yr respectively.

The impact of increasing greenhouse gas concentrations on the climate of Indian sub-continent and its variability is studied by using output from a time-dependent greenhouse warming simulation as well as a reference control experiment performed with the Hamburg global coupled atmosphere – ocean circulation model (Lal, M. et al., 1994). The onset date of the SW-monsoon over India along about 20°N inferred from the control run is similar to the observed onset data. With the exception of temperature, the projected changes in impact-related climatic variables over a period of 100 years are within the range of inter-annual variability in the monsoon region. There is no clear evidence for a significant change in the seasonal-mean monsoon rainfall or the variability of the monsoon rainfall in scenario-A experiment. The results obtained from the experiment suggest that the surface temperature could change by $\geq$ 2°K over the region in the next 100 years.

In another study on climatic scenario for Indian sub-continent (Kelly, P.M. and Hulme, M., 1993), utilizing 7 recent climatic models up to 2100 AD, the results show that the annual average temperature depict warming over the central part – close to that affecting global mean temperature. In the North, warming will be greater compared to South where it will be not as great (likely projection of about 1°C). For Himachal Pradesh (western Himalayas), the projected temperature and precipitation changes are annual temperature rise of about 3°C; winter temperature rise about 3°C, spring temperature rise about 7°C; Summer temperature rise about 4°C with a wide range of uncertainty. The annual precipitation change of +20%; winter change +30% to –15%; spring change + 30% to –20% and autumn change + 15% to –15%.

Modern science of global change is predominantly concentrated on the evaluation of the possible consequences of direct anthropological forcing currently imposed on the global environment. In biotic regulation of the environment, the problem is attacked from a different angle. Theoretical considerations, as well as extensive analysis of empirical evidence, testify in favour of the statement that the stability of the global environment is a function of the state of the natural biota of Earth. Natural biota appears as a powerful stabilizer of the environment when intact, and as a powerful de-stabilizer when disturbed. Global scale anthropogenical disturbances of natural biota, rather than direct anthropogenical pollution, appears to be the main cause of the present day global changes of the environment (Gorskhkov, V.G. et al 2000).

The long-term ecological safety of the global environment therefore requires that extensive territories are occupied by natural biota without human interference, rather than using technology-based strategies to deal with anthropogenical pollution. The book presents a quantitative estimate of the natural areas needed to stop the global change that emerged as a result of interdisciplinary research in a range of scientific fields, from climatological and forest ecology to evolutionary biology and bioenergetics.

3.13 WEATHER FORECASTING

Weather Forecasting is the process of issuing a statement of expected weather conditions for a specified area or portion of air space for a given duration (time scale). There are four types of weather forecastings for different time scales (Table 3.13.1).

TABLE 3.13.1

Weather Forecasting with Time Scales

Weather Forecasts	*Time Scales*
Very short range (Now casting)	Valid for six hours (<6 hrs)
Short range	Valid for one to two days (24 to 48 hrs)
Medium range	Valid for three to ten days (3 to 10 days)
Long range	Valid for a month or a season (>10 days)

* Kulshreshtha, S.M., 1998

Medium range weather forecasts are of maximum importance for agricultural operations for increasing the production.

Observations of atmospheric pressure, temperature, humidity, wind, sky condition, rainfall and weather at fixed hours from the network of meteorological observatories spread all over the globe form the prerequisite for weather forecasting. Apart from these observations on the surface of the earth or by balloon borne instruments, indirect measurements through weather satellites by remote sensing techniques are also available to fill the data gap in the areas where direct measurements are not available. Global meteorological network consists of around 12000 stations (11000 ground stations and 1000 selected merchant ships) besides 1200 radiosonde stations and aircraft and satellite observations.

In the conventional synoptic method of weather forecasting, the observations are plotted on weather charts which are analyzed to provide a three-dimensional state of atmosphere. The low and high pressure areas are identified. The likely movement of these and associated weather during next 24-48 hrs. are thereafter inferred. This method is somewhat subjective as the forecaster's experience plays a predominant role in its application.

The objective approach consists of solving various equations governing atmospheric motion and the physical processes, continuously taking place in the atmosphere. The equations of atmospheric motions, which are governed by the hydro-dynamical and thermo-dynamical properties of fluid, are very complex and they cannot be solved mathematically. However, their solutions can be obtained by a series of arithmetical calculations or numerical computations. Weather forecasting, which takes advantage of this process of solving relevant mathematical formulations of atmospheric changes is known as *Numerical Weather Prediction (NWP).* Numerical representation of the atmosphere and its phenomena over the entire earth, using the equations of motion and including radiation, photochemistry and the transfer of heat, water vapour, and momentum is performed in General Circulation Models (GCMs).

In practice, the application of NWP models for weather forecasting, has some inherent difficulties, mainly because of two reasons. Firstly, we are never able to define the initial state of the atmosphere perfectly due to lack of adequate observational data. Secondly, a precise mathematical formulation of the physical laws, governing the changes in the atmosphere is a complex problem and

exact analytical solutions of these equations are not possible due to non-linearities involved. The model equations have to be solved through computer-oriented numerical techniques. This itself is not an easily tractable problem. The numerical solutions are dependent to a great extent on the choice of boundary conditions and finite differencing methods which have to be designed carefully so as to ensure stable and realistic solutions. Notwithstanding these inherent limitations, the NWP approach has reached a high level of sophistication with advancement in the observational technology on one side and the computing technology on the other. It has been increasingly possible now to make the horizontal and vertical resolution of the models finer and to incorporate into them a variety of physical processes of the actual atmosphere .Models have shown vast improvement in their forecast skill over the years. Further improvement in weather prediction are possible if the observational technology is brought to a more advanced level.

In spite of all the improvements numerical models are still afflicted with systematic deficiencies. These are particularly serious in the tropics and probably are related to incorrect treatment of physical processes.

The National Centre for Medium Range Weather Forecasting (NCMRWF) at New Delhi of the Department of Science and Technology (DST) is actively participating in the project on Himalayan Mountain Meteorology with the Defence Research and Development Organisation (DRDO). Two meso – scale numerical models(MM5 and Eta) covering resolutions of 10-30 km and 32 km x 38 km are being run on a routine basis and the output products are being provided for snow and avalanche forecasting.

3.14 AGRO-METEOROLOGY

Agrometeorology or agricultural meteorology deals with the study of the interaction between meteorological and hydrological factors, on one hand and agriculture in the widest sense including horticulture, animal husbandry and forestry, on the other (WMO, 1992). It deals with both qualitative and quantitative relationships between weather conditions and the agricultural production. In general, agro-meteorological services are concerned with various aspects of farming, ranching, forestry including transportation of materials required for production and the produce for distribution to the consumer. The

weather has both benevolent and malevolent affects on crops. The destructive meteorological phenomena depending upon rainfall, temperature, radiation, winds and humidity affecting crops could be described broadly (Table 3.14.1).

TABLE 3.14.1

Crop Destructive Meteorological Phenomena*

Mateorological parameter	*Phenomena*	*Result*
Rainfall	- Excessive rain – floods } - Scanty rains – droughts } - Untimely rains- Storms/cyclones/ depressions-Thunder-storm/hail	- Devastation of crops over large areas - Damage or destruction - do - - do -
Temperature	- Cold wave-Heat wave	- Injury and stress to plants - do -
Radiation	- Defective insolation	- Affects the crop quality and yield
Winds	- Dust storms-Strong winds	- Physical damage to plants/crops
Humidity	- Excessive high - Extremely low	- Severe attack of insects, pests and diseases- Dessication of plants

*Source: Bahadur, J.et.al., 1990

It is widely recognized that weather based agrometeorological practices can help in selecting efficient crops for a region, schedules for sowing, irrigation, fertilizer application and chemical sprays and provide environmental protection to harvesting and post-harvesting operations resulting in large economic benefits. Agrometeorology in India started as early as 1932.The India Meteorology Department (IMD) established a special unit in Pune with nationwide network of agrometeorological observatories. Indian Council of Agricultural Research (ICAR) initiated agrometeorology with a coordinated crop-weather scheme in 1945. Since then there has been several developments (Bahadur, J et.al., 1990). Agromet Advisory Services for the Himalayan region, have been initiated by the National Centre

for Medium Range Weather Forecasting (Rathore, L.S. et. al. 1996). Strong need is felt to to improve our understanding of ocean-land-atmospheric interactions by conducting field experiments and measurements under the proposed Himalayan Experiment (Bahadur, J, 1999).

Crop growth models have been developed as research tools in agricultural meteorology dealing with following production situations

(i) the crop is optimally supplied with water and essential nutrients and grows without interference from weeds, pests and diseases. This gives potential production depending upon the type of crop, level of irradiance and thermal regime.

(ii) The crop is optimally supplied with all nutrients and grows without interference from weeds, pests and diseases but is subject to limited moisture availability.

Two types of crop weather models are employed in operational agrometeorology-statistical and simulation models. Crop simulation models are a combination of mathematical equations and logic used to conceptually represent a simplified crop production system. Dynamic simulation models have been developed to better understand the processes involved in crop production and to help take ameliorative measures. In order to develop a simulation model, a series of sub-models are required. The first few sub-models explain the development and growth of crop as controlled by temperature and radiation regime under non-limiting conditions. Other sub-models deal with the determination of soil moisture from corresponding weather products for production of plant-mass and assessing the loss due to pest and disease infestation. A number of models are available for different cropping systems and the decision support systems. However,there is need to design systems which integrate a broader range of models and analysis capabilities to provide decision makers with predictions of farm performance and resource requirements and to assess the variability and sustainability of agricultural systems.

In the country NCMRWF in collaboration with India Meteorological Deparment (IMD), Indian Council of Agricultural Research (ICAR) and State Agricultural Universities is providing Agro-meteorological Advisory Services (AAS), at the scale of Agro-Climatic Zone covering 2-4 districts, based on location specific Medium Range Weather Forecasts. The Indian Himalayan Region covers 25 agro-climatic zones but these services have been extended to 12 zones. (Table 3.14.2).

TABLE 3.14.2

The Status of Agromet Advisory Service Units in the Himalayan Region

State and agroclimatic zone	*Location*
Himachal Pradesh	
Sub-Montane and Low Hills	Solan*
Sub-Tropical Zone	
Mid Hills Sub-Humid ZoneHigh	Seoagh*
Hills Temperate Wet Zone	Mashobra
High Hills Temperate Dry Zone	Kukumseri
Jammu & Kashmir	
Low altitude Sub-Tropical Zone	Kukumseri
Mid tohigh altitude Intermediate Zone	Kukumseri
Mid to high altitude Temperate Zone	Srinagar*
Cold Arid Zone	Leh
Punjab	
Sub Montane Undulating Zone	Kandi
Undulating Plain Zone	Gurdaspur
Uttar Pradesh	
Hill Zone	Ranichauri*
Assam	
North bank Plain Zone	N.Lakhimpur
Upper Brahmaputra Valley Zone	Jorhat*
Central Brahmaputra Valley Zone	Shillongani*
Lower BrahmaputraValley Zone	Gosaigaon
Barak Valley Zone	Karimganj
Hill Zone	Diphu*
West Bengal	
Hill ZoneTerai Zone	Kalimpong*
Terai Zone	Pundibari
North Eastern Hills	
Alpine Zone	
Temperate Sub Alpine Zone	Dirang
Sub-TropicalHill Zone	Barapani*
Sub-Tropical Plain Zone	Barapani*
Mild Tropical Hill Zone	Medziphema
Mild Tropical Plain Zone	Lembucherra*

*AAS units already functioning

*Source : Rathore L.S. and Gupta, A (2002)

Medium Range Weather Forecasts cover five days based on 18- layer Global Spectrol Model (T-80) with a resolution of 150 km × 150 km on an operational basis. The Agro-met Advisory Bulletins contain location specific and crop specific farm level advisories prepared in local language and incorporate the available knowledge on crop-weather relationships. Feed-back on the worthiness of these services are being periodically obtained from farmers for further improvement.

For farm level management and decision-making processes the major components of models are vegetative and reproductive development, carbon balance, water balance and nitrogen balance. A good farm level management model has to meet the following criteria :

- It should be as simple as possible to keep computer memory requirements and running time to a minimum.
- It should make decisions on either a pre-seasonal or intra-seasonal basis, which includes multiple simulations to determine the outcome of management alternatives under a variety of possible weather regimes.
- The model should respond to variations in weather inputs, such as temperature, rainfall and radiation
- The model should respond accurately to drought, insect, disease, and nutrient stresses.
- The model should include and account for differences in crop phenological development which depends on variety, planting date, location and daily temperature.

Chapter 4

GEOSPHERIC AND HYDROLOGIC ASPECTS

4.1 INTRODUCTION

Normally *geosphere* is the solid mass of earth, as distinct from atmosphere and hydrosphere.Another definition of geosphere is lithosphere, hydrosphere and atmosphere combined (McGraw Hill Dictionary, 1983). This is due to strong coupling and interplay of forces operating constantly for a change in the environmental conditions.

4.2 OROGENY

Orogeny is the process by which mountain tracts are formed (also known as Orogenesis). Typically, orogenic belts are sites of abnormally thick accumulations of sedimentary and volcanic rock and severe deformation and thermal alterations.Mountain belts are objects of intense study, argument, and mystery for geologists. Their observable features, entirely land based, are exceedingly complex, primarily because of severe deformation, their internal features for the most part has been interpreted from surface data.

Seismological studies have provided much new information about the interior of orogenic belts. Seismological and oceanographic studies during the past several decades have revealed a globe-encircling, seismically active belt of mountains, called oceanic ridges and trenches with associated volcanic islands area; the oceanic ridge and trench system is fundamentally different from orogenic belts as perceived by Gilbert – an American Geologist who gave the theory of river development and erosion of valleys, volcanic intrusions – laccoliths. Models propose that orogeny is a consequence of evolution of oceanic ridges and trenches and continental drift. Orogeny results from interactions of this global, continuously evolving system of oceanic ridges and trenches, according to concept of sea floor

spreading or, currently lithosphere plate tectonics. Lithosphere plates are spherical segments of upper mantle and crust, varying in thickness from about 5 km at ridges to 150 km under central areas of continents, that are generated by growth of crust and mantle of oceanic ridges (accreting plate margins) and consumed in trenches (consuming plate margins or subduction zones). Plates move symmetrically away from ridges, over the low velocity channel of the mantle, with rates varying from 1 to 10 cm/yr.

The theory of plate tectonics provides a convenient framework for understanding the origin of earthquakes and the crustal deformations associated with them. Plate tectonics focuses primary attention on the mechanical and thermal properties of the earth. The lithosphere, which extends from the earth's surface to a depth of about 100 km. consists of crust and upper mantle. It is mechanically strong portion of the earth, broken into several large segments or plates. The lithospheric or tectonic plates move relative to one another at velocities of a few cms per year. More precisely, the relative motion of the plates is a small circle rotation. The rotation axis is a pole through the centre of the earth and a point on the earth's surface. The position of the pole is different for each pair of plates and varies over a long time scale. The rates at which the distances between points on various plates depend on two aspects. One is based on *geological data* averaged over a few million years. The other is *geodetic data* and is averaged over a few years. These two sets of data are in broad agreement, although, there are few notable disagreements which are subjects of current research (Encyclopedia of Earth System Science, 1991).

Plate motions profoundly influence other aspects of earth science and human ecology. On a geological time scale, the changing position of a continent is a primary factor in controlling the patterns of atmospheric and oceanic circulation. The volcanic input to the atmosphere during eruptions as the major source of important trace constituents such as sulphur. On the time scale of human elements, earthquakes are among the most devastating natural phenomena. Many of the most attractive residential environments have been created by fault motions and the attendant uplift of features along coast lines. Unfortunately, these environments are very unstable and subject to massive destruction during earthquakes, landslides and storm surges. Measurement of global sea level rise, as a consequence

of greenhouse warming are also ultimately connected to crustal deformation measurements. Apparent changes in sea level can be due to either oceanic process (e.g. ice sheet melting or water expansion with changes in temperature and salinity) or crustal deformation measurement sites. Thus, the interpretation of sea level change requires an understanding of crustal movement at the measuring site.

Geological evidence exists that the Himalayan mountain system has formed by violent crumpling of the earth's crust along the southern margin of the great table-land of Central Asia i.e.the Tibetan Plateau. Uplift of Himalayas was a gradual process protracted over a very long period. This process had a very marked effect upon the scenery, the topography and the river systems.

It is now believed that during the period 10 to 50 million years ago, the subcontinent of India, riding over its own tectonic plate, collided with the rest of the Euro-Asian land mass. The pressure squeezed the earth crust, forcing it to prop further inland. The uplift of Himalaya took place in three main phases (Thakur, V.C., 1999) (i) Early Miocene (70-21 m yr), (ii) Late Miocene (11-7 m yr) and (iii) Quaternary (1.6 m.yrs to the present). The estimates for the rates of uplift vary from 2 to 12 mm / yr, while the Tibetan Plateau has shown an average rate of uplift of about 5 mm/yr for last 10,000 yrs (Stone, P.B., 1992). The uplift is still continuing and is manifested in the form of regular earthquakes.

During the slow process of uplift, folding and faulting, the rivers were able to keep largely to their original courses. The erosive power of these streams was increased with the increase of bed slopes. Thus, the rivers are formed cutting through the main chains of ranges in deep traverse gorges after flowing long distances parallel to the trend of chain. Most of these rivers drain not only the southern slopes of the Himalayan mountains, but to a large extent, the northern Tibetan slopes as well. In fact, the watershed of the chain is not along the line of highest peaks, but quite a distance to the north of it.

Generally, the Himalayas are divided into three longitudinal zones with marked orographic features : *The Great Himalayan Range (Himadri),* rising above the snowline with average elevation of 6100 m. The range is composed of high-grade metamorphic and old granite rocks; *The Lesser Himalayan Ranges (Himachal)*, south of the Great Himalayas with average height of 2600-4600 m, are predominantly composed of mid to late Proterozoic sedimentary rocks overlain by

early granitic and metamorphic rocks, and *The Outer Himalayan Ranges (Siwaliks)* with average elevation from 1000 to 1300 m consisting of sedimentary deposits laid down by rivers in the channel and flood plains.The wide longitudinal valleys in between the lesser Himalaya the Siwaliks are called *'Duns'*in western and central Himalaya and *'Dwars* in eastern Himalaya'. This region is characterized by fault scarp,anticlinal valleys and synclinal ranges; the width, varies between 5-30 km and elevation between 300-1000 m.

4.3 GEOLOGY AND GEOMORPHOLOGY

Geology is the study of the Earth as a whole, its origin, structure, composition, and history (including the development of life), and the nature of the processes which have given rise to its present state. The word was first used in 1778. Geology comprises the following branches: *crystallography, mineralogy* (petrology and geochemistry) – concerned with the materials and composition of the Earth; *stratigraphy and historical geology, palaentology* – a study of past geological periods and fossils and *physical geology* including *geomorphology* which involves the study of the processes affecting the Earth and deals with the description and interpretation of land forms.

Himalayan geology and geomorphology are very complex due to intricate orogeny i.e. the mountain building which has been discussed in the earlier section. It encompasses a complex set of changes in rocks both at depth (metamorphism, magnetism and structural deformation) and on the surface (uplift and denudation) Fig. 4.3.1 shows a geological map of the Himalayan orogen with the following divisions from north to south (Sorkhabi, R.B. and Arita, K., 1997).

(i) the Trans-Himalayan and Kohistan – Ladakh Batholith – the intrusive mass of igneous granite (Cretaceous – Eocene)
(ii) the Indus-Tsangpo Suture Zone, marking the initial plate boundary between the Indian and Asian tectonic plates along which Tethys ocean (a Mesozoic geosyncline which developed between Laurasia and Gondwanaland and covered southern Europe, the Mediterranean, North Africa, Iran and the Himalayan region, possibly extending into Burma and south-east Asia) closed.
(iii) The Tethys Himalaya representing the Cambrian – Eocene

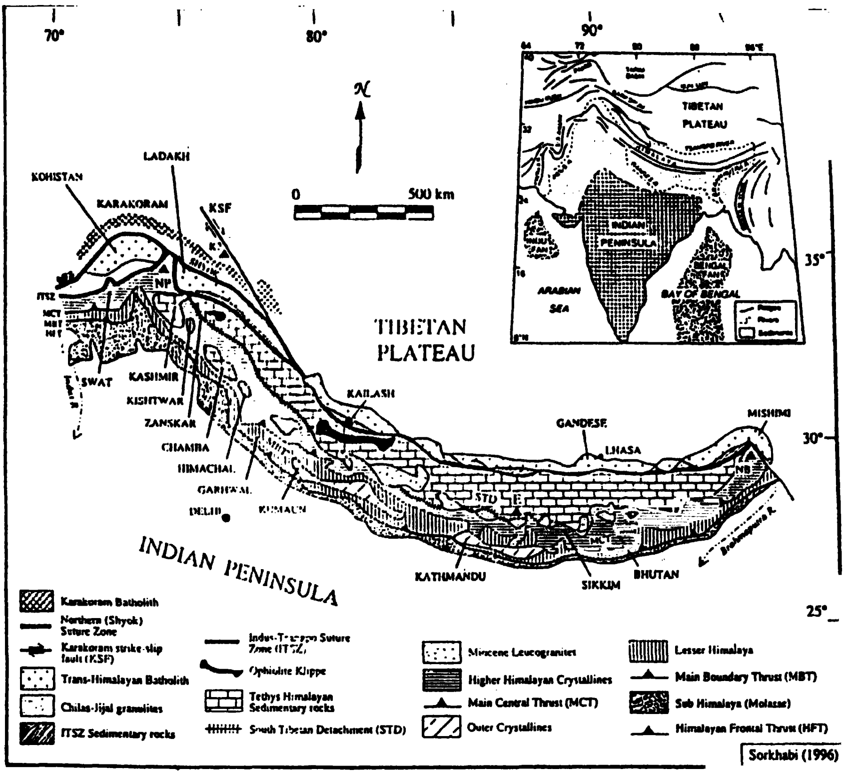


Fig. 4.3.1 Geological Map of Himalayan Orogen

marine sediments of the Tethys deposited on the northern margin of the Indian plate.

(iv) The Higher Himalayan Crystalline Complex, composed of amphibolite facies metamorphic rocks and Tertiary granites.

(v) The Lesser Himalaya consisting of Precambrian – Paleozoic sediments and low grade meta – sediments and various pre-Himalayan granites.

(vi) The Sub-Himalaya (or the Siwalik Hills) containing freshwater sediments of Cenozoic age deposited in the foreland basin of the Himalaya.

These lithotectonic divisions are bounded by large scale faults shown in the geological map of the Himalaya.

The arcuate Himalayan mountain chains have risen against the older established river courses of the Indus, Sutlej and Brahmaputra. Emerging from the northern ranges and flowing longitudinally for

several hundred kms north of the barrier, these rivers now pass through deep antecedent gorges to the Indo-Gangetic Plains, Due to the long intense forces of Alpine Himalayan orogeny, the old land surfaces have been changed completely. Simultaneously, the intermittent emergence and submergence of the land masses throughout the orogeny, the extent and configuration of the Tethys also changed, but continued to be a zone of accumulation and sedimentation almost till Cretaceous (abut 65 m yrs ago). It is certain that during the intervening periods of tectonic episodes, a series of landscapes were carved out. However, due to intense thrust movements, nappe structures, steep fault scarps and the present gagged terrain, it is difficult to establish the cyclic evolution of the landscape development. Nevertheless, from the shape of the hills, plateau and the configuration of the valleys, presence of lakes and their lacustrine deposits at higher levels etc., it is evident that the Himalayan region has experienced several mountain building episodes during the late Cainozoic period (65 m yr to 2 myr ago). The intermittent Pleistocene glacial activity and deep carvings due to river action are notable features of the Quaternary times (0 to 2 m yr ago). Summing up, the modern Himalaya is a result of thrustsheets and overfolds are over-ridden by reliefs of earlier smooth planation of mid Tertiary age. The anticlines, synclines and other isoclinal folds so created have been carved and denuded by the now receding glaciers and large scale river erosion in the sub-recent and recent times. The phenomena of uplifts is still in progress and is marked by the frequent earthquakes. The lofty Himalayan system have thus been sculptured and present the beautiful scenery through a process of complicated phenomenon.

Geomorphology deals with the description and interpretations of landforms. A recent development in applied geomorphology has been the use of landforms and sediments to identify potentially hazardous sites for land use planning and management purposes (Gardner, J.S., et. el., 1992). In Himalayan region, large altitudinal ranges produce sharp variations and gradations of microclimatic from tropical to subtropical conditions at lower elevations to Arctic and sub-Arctic conditions at higher elevations. Centuries of human occupance and intensive land-use have modified most of the vegetative indicators and some of the geomorphological indicators of hazardous sites, producing a special challenge in landscape interpretation. Multiple identification criteria for mapping and field observations have been

listed by the above investigators for natural hazards e.g. snow avalanches, rockfalls, debris flows, landslides, torrents, floods etc. as natural hazards research encompasses concepts, methods, and techniques from the wide range of natural and social sciences (See Section 6.7 of the text). This has to take place increasingly to manage the exclusive dimensions of natural hazards in the Himalayan region.

4.4 GEO-TECTONICS AND GEODYNAMICS

Geotectonics is the study of the broad structure of a region. Very young in age, the rugged Himalaya continues to be seized repeatedly with the spells of tectonic restlessness or crustal disturbances. The disturbances indicate accumulating inner tectonic stresses in the crust. The giant body of the mountain quivers in some segments or twitches spasmodically and breaks up violently in other places. These are manifestations of the tectonic turmoil's of growth, for the Himalaya is still growing. The role once played by the Main Central Thrust (MCT) in the birth of the Himalaya is now being played by the Main Boundary Thrust (MBT). In a few million years from now, it is expected that a new intra-continental thrust would probably appear further south of the MBT to continue the growth of the mighty Himalaya. Consequently, the mountain framework of structure is recurrently deformed and the landscape has been reshaped time and again (Valdiya, K.S., 1998).

The *Geodynamics* of the Himalayan region is basically controlled by the fact that the Indian landmass continues to move northwards and press the Asian subcontinent. This results in building up stresses and strains and accumulating them progressively in the fractured frame of the Himalayan mountain system. Release of these stresses results in natural hazards e.g. earthquake, landslide etc.

Repeated geodetic and geophysical surveys conducted by the Survey of India show that the isostatic equilibrium (the concept of *isostasy* depends upon the model of the Earth's crust in which lighter ,continental masses 'float' on a denser substratum) does not prevail in the great Himalayan ranges. Repeated observations from Indo-Gangetic Plains to Lesser Himalayas over 60 to 70 years show that a upliftment of mountains at a rate of 1.5 to 2 mm/yr is taking place (Issar, D.P., 1999). The investigations revealed that the movement of crust in horizontal and vertical planes do not take place uniformly all over the mountain region. There are regions of high and low activity

where rock expansion and contraction results in crustal upliftment and subsidence.

4.5 MINERAL WEALTH

The Indian Himalayas are a rich and diverse source of minerals. Presently, about 25000 ha area is under surface mining, located predominantly in the forests. It is estimated that 2 to 2.5 ha additional area is degraded from one ha to effective mining.

Mineral reserves of magnesite, dolomite, cement-grade limestone, roofing slate, paving stone and gypsum are very large and economically very promising. Other minerals like steatite-talc, phosporite lignite, rock salt, base-metals, uranium-minerals etc. are substantial although their mining at present is not economically profitable or viable. (Valdiya, K.S., 1997). These are notable deposits of high-cost but low volume minerals occurring in various parts of the Himalayas. These deposits can be mined in times of acute need and emergency.

TABLE 4.5.1

Mineral Wealth of the Himalayas within the Indian Territory*

Mineral	*Proven Reserves*	*Mineral*	*Proven Reserves*
Limestone	458 m.t	Dolomite	94 m.t.
Magnesite	82.2 m.t	Gypsum	66.7 m.t
Graphite	26.7 m.t	Lignite	21.7 m.t
Phosphorite	18.1 m.t	Bauxite	13.6 m.t
Coal	11.6 m.t	Rock Salt	8.0 m.t
Copper-Lead-Zinc	2.2 m.t	Steatite-Talc	1.9 m.t
Fluorite	86,000 t	Bentonite	40, 000 t
Sulphur	20,000 t	Barytes	13,200 t
Antimony	10,588 t	Borax	5,423 t
Uranium minerals	Appreciable		

*Source: Thakur, V.C., 1976

Since minerals form the base of all industrial, economic and commercial activities, and are used for the generation of energy that touches all spheres of life of the common man, workable deposits of

minerals must be mined. Establishment of slate and paving stone industry would prove very beneficial and greatly rewarding. However, this is to be done with minimum waste in extraction and rigorous adoption of scientific and systematic methods of mining, so that integrity of the environment is not violated and its ecological balance is maintained.

Mining of quite a few mineral deposits has created environmental problems in a number of areas due to lack of safeguards against scarification of landscape and triggering of mass-movement. Consequently, many mining areas have become open wounds and scarred wastelands of barren slopes and eroding soil. Down-slope, stream beds have been clogged with debris, and springs and vegetation buried and smothered by sedimentary wastes. There should be legal binding on miners to restore the land by resorting to systematic and appropriate methods of disposal of wastes and debris, and regeneration of vegetal cover and stabilization of the slopes.

4.6 GEOTHERMAL ENERGY

There are a large number of springs emitting heated water and steam in fault zones (Fig 4.6.1), particularly the Indus-Tsangpo Suture in Ladakh, the Main Central Thrust (MCT) and Main Boundary Thrust (MBT) There are 34 hot springs in Ladakh, 34 in Himachal Pradesh,

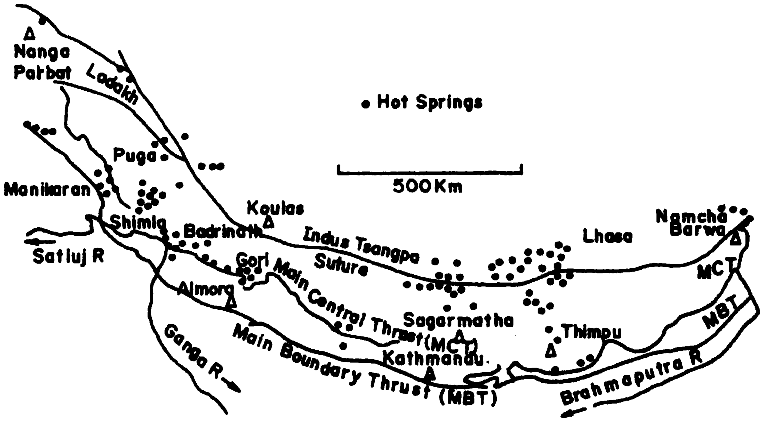


Fig. 4.6.1 Hot Springs located in Zones of Deep Faults that define the tectonic boundaries of the Himalayan Terrane

37 in Kumaun, 7 in Sikkim, and 11 in Arunachal Pradesh. These hot springs have the potential of generating power at the rate varying from 130 milli W/m^2 to 468 milli W/m^2·the high value of 300 milli W/m^2 being in the Ladakh belt. (Shankar, R., 1989).

The energy from hot springs can be profitably utilized for local development, as is being done in Ladakh. There are two ways in which the geothermal energy can be utilized. The hot water and superheated steam can be directly conveyed to power plants to operate generating turbines. The hot water and steam can be used to heat buildings for human comfort and glass houses for growing vegetables. (Valdiya, K.S., 1997).

Geothermal studies of the latter accessible depths should be expanded and carried out systematically to include larger territories of potential importance. The information obtained could serve as a basis for knowledge of the thermal state and thermal history of the earth and accordingly of more general laws of its development. Such investigations will doubtlessly prove to be of tremendous practical importance in opening up new vistas for supplementing our thermal power from other fossil fuels.

4.7 GLACIATIONS

The term *'glaciation'* embraces both the processes and the results of erosion and deposition arising from the presence of an ice-mass on a landscape, and is applied to these phenomena, whether on a continental scale ,or within the confines of a valley. Study of glacial deposits and landforms shows that the glacial history of the Pleistocene Epoch consisted not of a single cycle of growth and disappearance of ice sheets, but rather of four such cycles, each referred as a glacial stage. Long periods of warm climate (interglacial stages) separate the glacial stages. During interglacials, the plants and animals are known to thrive as indicated by the remains of plants (peats) and animals. It is generally observed that the glacial stages, marked by advance of ice-sheets and corresponding cold climate, were of much shorter duration than the interglacial stages, with relatively mild climate.

Unlike Europe and North America, Asia was not covered by continental ice sheets during Quaternary period (last 2 million years). It is represented by local accumulation of glacial (Pleistocene i.e. period from 2 million years ago to 10,000 years B.P.) and postglacial

(Holocene i.e. from 10,000 years B.P, to the present) deposits which continue without change of fauna. During Pleistocene, the glaciers occupied about 30 percent of the total area of the Earth's land surface as against 10 percent at the present. The Quaternary appears to be an artificial division of time to separate pre-human and post-human sedimentation.

The most recent glaciation on earth reached its maximum advance about 20,000 years ago. Moving downhill up to several meters a day, the ice (nearly 1600 meters deep at places) scrapped the earth like a giant bulldozer, pulverizing the rock before it. As the earth warmed, the glaciers retreated up the steep valleys, and the melt-waters at the leading edge of the ice put down thick layers of loess in the lowlands.

Ice ages give us clue about the appearance of man at different places. It is now widely accepted that the early man *(Homoerectus)* first arose in Africa between one million to two million years ago. Scientists unearthed bones buried in China's loess, belonging to Lantian man, who lived about 600,000 years ago. Near Beijing, they found bones belonging to the Peiking man, who lived between 500,000 to 250,000 years ago. Modern man *(Homosapiens)* did not appear in Asia until 50,000 years ago. (Bodo, R. 1990).

Himalayan glaciation has been a controversial issue for a long time. Throughout the Himalayan region, extensive evidence of past glaciation is provided by well developed moraines and valley fills that exceed several tens of metres in thickness. Although relative chronologies have been established for several parts of the Himalayas, the timing of glaciation is poorly understood because of paucity of suitable dating material. Researchers have often assumed that Himalayan glaciations were synchronous with global ice-volume maxima (Zheng, B., 1989; Burbank, D.W & Kang, J.C. 1991; Anderson, D.M. & Prell, W.L. 1993; Emeis, K.C., Anderson, D.M., Doose, H ; Kroon, D & Schulz-Bull, D., 1995) implying that the climatic change in Himalaya is tied to temperature cycles in the northern mid-latitudes. However, new dates do not support this assumption (Gillespie, A. & Molnar, P., 1995; Sharma, M.C. & Owen, L.A., 1996; Owen, L.A., et.al, 1997), suggesting that the influences on climatic change in Himalayas are more complex than previously thought. A review of the currently available dating evidence (Benn, D.I. & Owen, L.A., 1998).for the timing of Himalayan glaciations and paleoclimatic records from adjacent regions, examined the possible implications for climate dynamics in the region. Himalayan

glacier fluctuations are controlled by variations in both the South Asian monsoon and the mid-latitude westerlies. It is concluded that the glaciers in this region were less extensive during global glacial maxima due to increased continentality of the climate of High Asia.

4.7.1 Snow Cover

Snow is the solid form of water which grows while floating, rising or falling in the free air of the atmosphere. A natural snow crystal is an intriguingly beautiful creation and has a sand particle at its centre. Snow crystals have infinite variety of forms and shapes. More than 6000 different forms of crystals have been photographed but this listing is still considered incomplete (Upadhyay, D.S., 1995). Three basic forms of snow crystals are: a hexagonal prismatic column, a thin hexagonal plate and a branching star shaped form, sometimes called dendritic. Various forms of snow crystals are associated with the temperature of the surroundings. Grain size of the snow crystals refer to the size (length) of the majority of crystals in a given sample. It could range from less than 0.5 mm to more than 4 mm. Freshly fallen snow crystals have a density as low as 0.01 g/cc i.e. a mixture of 1% moisture and 99% of air. The textural and physical properties of snow continuously change as the crystals deform and density changes occur. The density of snow forms of various types (Paterson, W.S.B., 1969) are new snow at low temperatures in calm weather (0.01-0.03 g/cc); immediately after falling in calm (0.05-0.07 g/cc); damp new snow (0.1-0.2 g/cc); settled snow (0.2 to 0.3 g/cc); depth hoar (0.2 to 0.3 g/cc); wind packed snow (0.35 to 0.4 g/cc); firn (0.4 to 0.85 g/cc); very wet snow and firn (0.7 to 0.8 g/cc) and glacier ice (0.85 to 0.91 g/cc).

A sufficient area of the high Himalaya lies higher than the snow line (isotherm 0°C) and in this area, snow falls round the year. It is estimated that 10 to 20% of the local surface area is covered by glaciers while an additional area ranging from 30 to 40% is overlain by seasonal snow cover in the mountain region.

Snow cover in the Himalayas occurs and exists depending on the terrain and climatic conditions of the region. The snow cover could be *temporary*, *seasonal* or *permanent*. The temporary snow cover stays for a few days and then melts away. It occurs at lower altitudes during winter and even sometimes at higher altitudes during summer. The snow cover that is formed over weeks or months by consecutive

snow falls and which melts away gradually during the following summer, is termed as seasonal snow cover. Above a certain altitude and in certain situations, some amount of snow is carried over to the next winter season without melting away during summer, and this turns into firn and ultimately ice adding to the permanent snowfields and glaciers. It is the seasonal snow pack that contributes to the water resources during the lean summer months (April, May, June) and is thus most important. The duration for which seasonal snow pack stays is variable with respect to basin location and also from year to year.

No consolidated information is available for snow cover over the Indian Himalayas. However, it may be interesting to note that the inter-annual variability of Himalayan snow cover is substantially large (Bamzai, A.S and Klinter, J.L., 1997).

TABLE 4.7.1

Inter-annual Variability of Himalayan snow Cover (10^6 Km^2)*

Winter Season		*Spring Season*		*Summer Season*	
Mean	S.D.	Mean	S.D.	Mean	S.D.
2.20	1.25	1.11	0.73	48.48	0.43

where S.D. stands for standard deviation.

*Source: Bamzai, A.S. and Klinter, J.L., 1997

Dynamic characteristics of snow cover in Western China (Peiji, L, 1994) presents a detailed and accurate spatial pattern, seasonal cycle and year to year variability of snow cover for a 30 year period (1957-1987) by using the best information derived from snow depth charts, employing data from Scanning Microwave Multi-channel Radiometer (SMMR), operational NOAA digitized weekly snow cover extent charts (Fig 4.7.1), short wave Defense Meteorological Satellite Programme (DMSP) imagery, in conjunction with daily snow depth records for 175 ground climate stations.

The results show that the snow season begins in mid September over the Tibetan Plateau. From mid October to early November snow cover development is rapid. It increases to late November – early February. The peak with maximum snow cover occurs in January, showing snow cover area of about 1.5×10^6 km^2. This is followed by a slow decline until June. During the growth progression of snow cover, the increase in a real extent leads to snow volume increase,

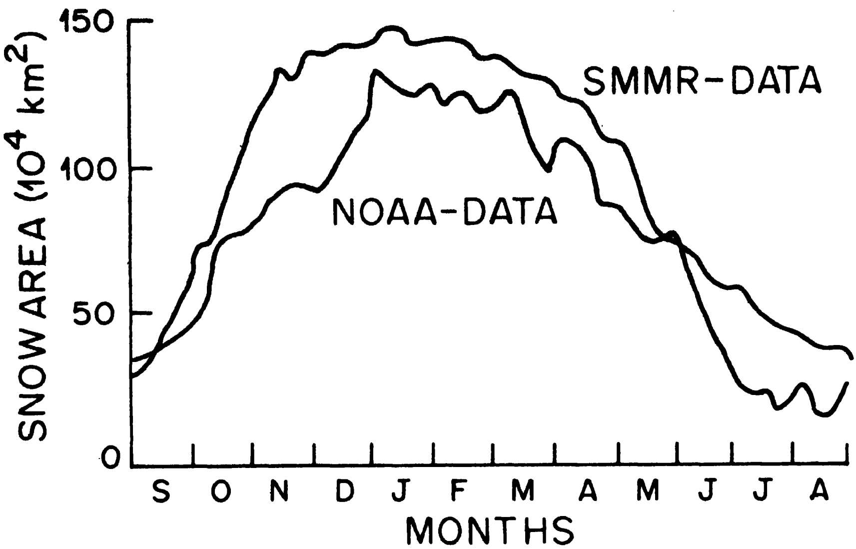


Fig. 4.7.1 Normal Annual Cycles of Himalayan Snow Cover

while the decay phase, decrease in snow volume is followed by decrease in snow area. The seasonal progress of snow cover in lowlands of western China, derived from station data is different from that of Tibet in two ways. In lowlands, the snow begins one month later and ends two months earlier. The winter, spring and autumn are represented by 45.2%, 28% and 21.2% of the snow volume respectively over the Tibetan Plateau. The larger year to year variability of snow cover is it's most striking feature. The variance in snow volume is more noticeable than that in snow cover area. The ratio between the highest annual volume and the lowest is 1.91 for the Tibetan Plateau and 1.39 for Western China while the area ratio is 1.59 and 1.27 respectively.

Himalayan snow cover is important for weather forecasting on various time scales. Maximum snow cover results in maximum zonality (E-W air circulations) while minimum snow cover supports maximum meridionality (N-S air circulations). Variable snow cover introduces horizontal temperature gradient resulting in cyclogenesis and blocking, modifying weather. The positive energy feed back from snow enhances the sensitivity of the earth-ocean-atmospheric system. Snow cover oscillations are found to be related to monsoon activity (Vernekar, A.D. 1999).The strong freeze- thaw cycle in the Himalayan region due to large fluctuations of temperatures, is responsible for

greater erosion of surface soil/rock formations and also for excessive melt-water generation.

Probably, the greatest importance of snow and ice is biological. It provides insulation protecting the plants and small animals to survive the severity of winter. Frozen lakes or rivers prevents the loss of too great a quantity of heat, protecting the aquatic flora and fauna from cold injuries. The melting of snow and ice covers, the retention of the liquid melt-water and the release of soluble nutrients, stimulate the growth of complex microbial communities thus playing a role for biogeochemical cycling and snow-ecosystem interaction.

4.7.2 Glacial Cover

In simplest term, a *glacier* can be defined as a body of natural land borne ice that flows. It can also be called as a river of ice. A glacier constantly changes its shape and form to adjust to the changing environmental conditions. It is, therefore, called the *living ice.* Glaciers occur in those parts of the earth where the rate of snow precipitation is greater than the rate of melting of snow. The ideal locations are the polar regions and the high mountain ranges. The glaciers are classified depending on morphological (area-altitude) characteristics, thermal conditions and their dynamic behaviour. The glaciers move due to internal flow of ice and slippage over bed rock. Warm glaciers move more rapidly. The increased velocity results in extending ice flow and the glacier advances and thins.The decrease in a glacier's velocity results in compressive ice flow and the glacier shrinks and thickens.In view of a kinematic wave, increased discharge occurs through a glacier. On account of a glacier surge, a large and rapid increase in basal slip occurs and the glaciers move very rapidly creating hazardous situation for the downstream inhabitants.

The mass balance for a complete glacier involves input by direct precipitation, condensation, wind transport, and avalanches versus melting and runoff, evaporation wind transport and ice flow (feeding avalanches or calving sites in lakes). Like any other material, ice deforms elastically, with a true modulus of ~90 kilo-bars that is not sensitive to temperature.

Unlike Europe and North America, Asia was not covered by a continental ice sheet (ice age) during the Quaternary (geological period of last 2 million years ago). It was rather covered by local glacial cover on its high mountains. During the Pleistocene (geological

period from 2 million yrs ago to 10,000 yrs B.P), the glaciers on the Earth occupied 30% of the total area of the earth's land surface as against 10% at the present (Williams, Jr.R.S., 1986).As discussed before, the most recent glaciation on earth, reached its maximum advance about 20,000 yrs ago. Moving down hill at up to several metres a day, the ice – nearly 1600 meter deep in places, scrapped the earth like a giant bull-dozer, pulverizing the rocks before it (Bode, R, 1990). Ice ages give us a clue for the appearance and migration of man. It is now widely accepted that the early man *(Homoerectus)* first arose in Africa between 1 million to 2 million years ago. Scientists unearthed bones buried in China loess, belonging to Lantian man, who lived about 600,000 years ago. Near Beijing, they found bones belonging to the Peking man who lived between 500,000 to 200,000 years ago. Modern man *(Homosapian)* did not appear in Asia until 50,000 years ago.

Glaciers of high Asia cover an area of about 50 per cent of all glaciers outside the polar region. Their areal extent is 33 times the glacier area occupied by the European Alps. The following table gives an approximate distribution of permanent snow and ice in Himalayan mountains (Upadhyay, D.S. 1995) having a significant cooling effect on their immediate neighbourhood, the regional and the global environment.

TABLE 4.7.2.1

Distribution of Permanent Snow and Ice in Himalayan Mountains*

Sub-region	*Extent of permanent snow and ice*	
	Volume (Km^3)	*Surface Area (Km^2)*
Hindukush	930	6,200
Karakoram	2,180	15,670
Himalayas	5,000	43,000
Tibet	4,800	32,150
Total	12,930	97,020

*Source: Upadhyay, D.S., 1995

In 1984, Chinese scientists have published details of glaciers on Qinghai–Xizang plateau (Jigun, L and Shuying X., 1984) The percentage glacier area is shown in brackets in Fig 4.7.2.1 for various

mountain systems. It is claimed that 49.8 per cent of these glaciers lie in Chinese territory as shown in the table 4.7.2.2:

TABLE 4.7.2.2

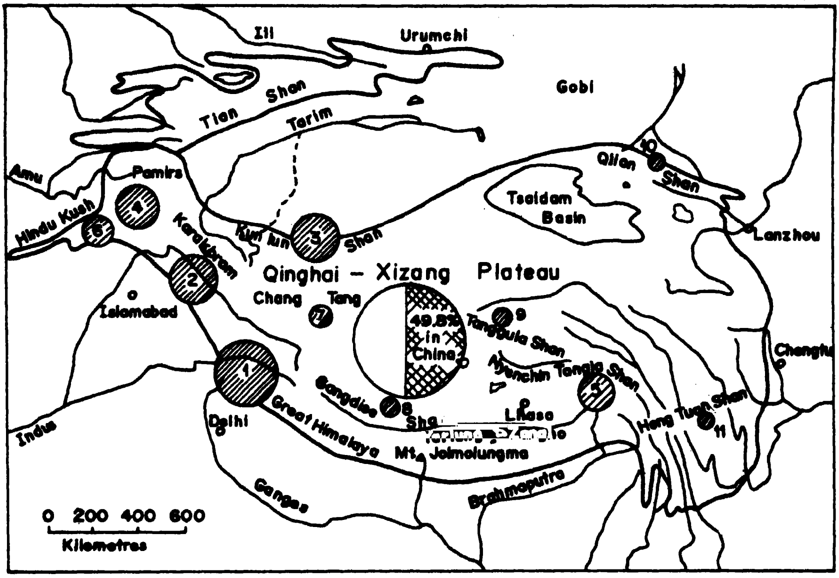
Glaciers on the Qinghai – Xizang Plateau and its Marginal Mountain Ranges*

S.No	*Mountain ranges*	*Glacier Area*		*Glacier Area within Chinese territory (Km^2)*
		Area (Km^2)	*Percentage*	
1.	Himalayas	29,685	31	11,055
2.	Karakoram	17,835	19	3,265
3.	Kunlun	11,639	12	11,639
4.	Pamirs	10,304	11	2,263
5.	Nyenchin	7,536	8	7,536
6.	Hindukush Tangla Shan	6,200	7	0
7.	Chang Tang	3,566	4	3,566
8.	Gangdise Shan	2,188	2	2,188
9.	Tangulla Shan	2,082	2	2,082
10.	Qilian Shan	2,063	2	2,063
11.	Hing Tuan Shan	1,456	2	1,456
	Total	94,554	100	47,113

* Source: Jigun, L., Shuying, X, 1984.

The glaciers on different ranges exist in an altitude range varying from lower than 4000 to more than 6200 m and the maximum altitude range is covered by the Himalayan glaciers due to high precipitation on higher ranges. Out of several thousands of glaciers, some very important glaciers were listed (Bahadur, J., 1972) along with their lengths and the region of their existence to point out the importance of their active role in modifying the Himalayan environment.

The snowline, or the lowest limit of perpetual snow on the southern slopes of Himalayas, varies from 4300 m in eastern Himalaya to 5800 m in the western. On the Tibetan side, the snowline is about 900 m higher owing to desiccation caused by the absence of moisture bearing winds. However, the permanent snowline on glaciers in western Himalaya is lower (4250 m) due to difference in latitudes



HIMALAYAN INCLUDING TIBET

Fig. 4.7.2.1 Distribution of Himalayan Glaciers including Tibet

and higher winter precipitation as compared to that in eastern Himalayas (4570 m).

TABLE 4.7.2.3

Some Important Glaciers in Himalayas*

Region	*Name of the glacier*	*Approximate length (Km)*
Eastern Hmalayas (Sikkim)	Zemu	26
	Kanchanjunga	16
Central Himalayas (Uttaranchal)	Milam	19
	Kedarnath	15
	Gangotri	26
	Kosa	11
	Rupal	16
	Diyamir	11
Western Himalayas Himachal Pradesh / Jammu & Kashmir	Sonapani	11
	Rundun	19
	Punmah	27
	Rimo	40
	Chong Kumdon	19

(Contd.)

(Table 4.7.2.3 Contd.)

Region	*Name of the glacier*	*Approximate length (Km)*
	Nivapin	NA
	Biafo	63
North Western	Hispar	61
Himalayas Karakoram	Baltoro	58
Pakistan/	Gasherbrum	39
(Jammu & Kashmir)	Chogo Lungma	72
	Siachin	58

*Source: (Bahadur, J., 1972)

Himalayan glaciers differ from those in the Alps and other high altitude glaciers in the following features :

(1) Debris cover over the glacier surface is more dense particularly in the ablation zone. Dust spread is also more as a consequence of mechanical destruction of rocks and boulders. In addition, there is a significant quantity of biomass and bacterial spread over the Himalayan glacier surface. Hence, these glaciers have blackish or brownish or an unshining look compared to the mountain glacier of higher latitude. This reduces surface albedo to 10 to 20% or even less on many glaciers.

(2) Summer temperature over the Himalayan glaciers is higher particularly on southern slopes. It is usually above 10°C. Occasionally, temperatures of 18-20°C are also experienced at lower altitudes, resulting in more liquid water content of the snow and the firn layers.

Both the above features tend to enhance melt rate resulting into large water yield to river runoff..

Glaciers, being the progeny of climate, interact with it and also its change at different scales thereby influencing weather and climate. The climate on earth-ocean-atmosphere (EOA) system has fluctuated between temperature limits up to 15°C for hundreds of million of years (Sharp, R.P. 1988). General trends in global climate change for various time-scales ranging from decades to hundreds of million years have been the topic of studies by several earth scientists. Paleoclimatic situations have been reconstructed from the glacial ice cores. (Thompson, L.G. et.al 1989).

Glacier fluctuations affect the regional hydrology of the glaciated catchments. The shrinkage of glaciers, following the end of the Little

Ice Age (LIA) i.e. 1520 to 1880 AD, is a major reflection of the fact that rapid secular changes in the energy balance of the earth surface are taking place at a global scale. This global signal of atmospheric warming not only concerns the recent past but must be considered as one of the key parameter for early detection of man induced warming in the near future. Within the complex chain of processes linking climate and glaciers, glacier mass balances are most directly related to changes in atmospheric conditions.

The snow and ice over Himalayan mountain system form a cold natural water reservoir whose meltwater contributions regulate the water supply throughout the year to our northern river systems. *It is important to note that the water yield from a Himalayan catchment*

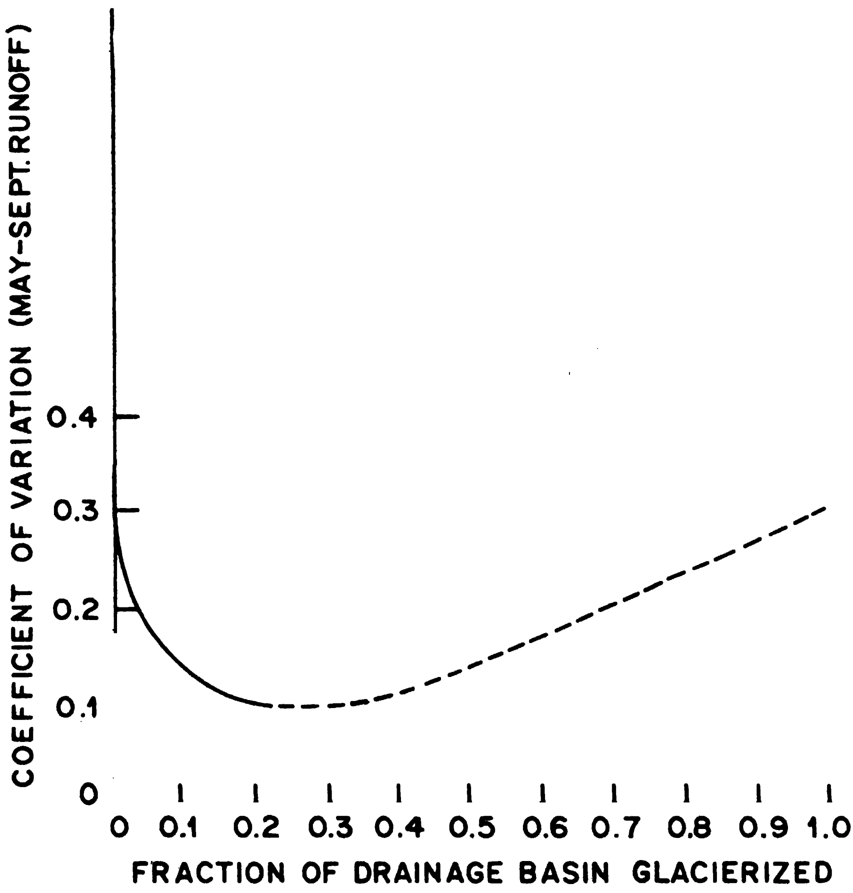


Fig. 4.7.2.2 Moderation of Water Discharges of Glaciated Streams

area is roughly double that of an equivalent catchment area from peninsular India due to larger precipitation on the high mountains.

In any one year, glacier runoff may be greater or less than that year's precipitation because glacier runoff increases if the precipitation is deficient (drought year) and it decreases if the precipitation is greater than normal (flood year). Thus, glaciers act as buffers and regulate the runoff from high mountains. Studies have shown that a glacier cover of 10% of a basin area (Fig 4.7.2.2) causes the stream flow variability to drop to half that of non-glacierized value (Meier, M.F. and Roots, E.F., 1982). Basic requirements for understanding and proper management of mountain water resources require a knowledge of the amount and location of stored frozen water, the pattern of water release by melting, and how these patterns release depend on short term weather and long term climatic changes. Briefly we can enumerate following merits for the importance of Himalayan glaciers:

(i) They exert a great cooling or refrigerating effect on the surroundings.

(ii) They constantly interact with weather and climate both in temporal and spatial domains.

(iii) They work as water supply reservoirs, releasing more water under drought conditions of less precipitation and less water under flood conditions caused by large precipitation.

(iv) Due to their high altitude location, they provide a larger fall of water, of great advantage for the production of cheap hydroelectric power.

(v) The enormous snow and ice fields not only act as reservoirs for terrestrial and aquatic species but also for snow micro-organisms. The melting of snow and ice cover, the retention of liquid meltwater and the release of soluble nutrients in the high altitude environment stimulate the growth of complex microbial communities, influencing the biodiversity of the region (IAHS, 1994).

4.7.3 Glacier Inventory

An inventory of mountain glaciers (other than the ice sheets of Antarctica and Greenland, which cover about 97 per cent of the ice covered area of the Earth) covering 3 per cent of the glacierized area, is of direct importance to mankind for providing water for irrigation, industry, hydro power, recreation and domestic supplies. The

collection and publication of the data on the world's glaciers were systematized by UNESCO/IASH/ICSI from 1970. Since 1986, a World Glacier Monitoring Service (WGMS) in the Global Environment Monitoring System (GEMS was established by the United Nations Environment Program (UNEP). WGMS is now entrusted with the collection of standardized data on the extension of glaciers existing in the glaciated regions of the world for the production of a World Glacier Inventory (WGI) .This is expected to provide a baseline for future monitoring of the world's glacierized regions.

TABLE 4.7.3.1

Status of Glacier Inventory of the Indian Himalaya

Basins			*Number of Glaciers*	*Glacierised Area (km^2)*	*Ice Volume (km^2)*
1. INDUS BASIN					
Shyok, Nubra, Indus, Gilgit, Kishanganga, Jhelum, Chenab, Ravi, Beas, Satluj					
(A)	Detailed	Jhelum	133	94.18	3.30
	Assessment	Part of Satluj	224	420.60	22.99
	(selected basins)				
(B)	Regional	Remaining	3398	33,382.00	
	Assessment	Basins		33,896.78	
	TOTAL		3755	Say 33,897	26.29
2. GANGA/BRAHMAPUTRA BASIN					
Alaknanda , Bhagirathi, Kaliganga, Yamuna, Tista, Brhamaputra (In Arunachal Pradesh)					
(A)	Detailed	BhagirathiTista	238	755.43	67.02
	Assessment		449	705.54	39.61
	(selected basins)				
(B)	Regional Assessment	Brahmaputra (Arunachal Himalaya)	161	223.37	9.96
	TOTAL	Remaining Basins	640	4062.34	116.59
				Say 4062	
Total Number of Glaciers identified			:	5,243	
Total Glacierised Area (After integrating A&B)			:	37,959 km^2	
Ice Volume (For Glaciers at A)			:	142.88 km^3	

* Source : Kaul, M.K., 1999.

Using IRS-1A and Landsat Satellite data of period between middle of August and September for glacier investigations (as snow cover is minimum and glaciers are fully exposed), Glacier inventory maps were prepared on 1:250,000. 1702 glaciers were identified covering an area of 23,314.93 km^2 (Kulkarni, A.V., 1991). Following the international guidelines,the Geological Survey of India prepared a first generation inventory in 1983 showing that the country has 4795 glaciers and a glacier covered area of 38,479 km^2. This inventory has been updated showing 5243 glaciers, covering 37,959 km^2 lie in Indian territory. (Kaul, M.K., 1999). This information is being further updated as about 7500 glaciers have been identified.

Yet another effort was made by Survey of India (Issar, D.P., 2000) to prepare an inventory of major glaciers of the Indian Himalayas. This inventory is prepared statewise.327 major valleys have been identified. Out of these 60 glaciers are from J&K and Ladakh, 85 from H.P., 62 from Uttranchal and 20 from Sikkim Himalayas. Distribution of these glaciers are shown on 1:1 million scale.

A recent inventory of glaciers, glacier lakes published by ICIMOD of Bhutan (Mool, P.K., et. al 2001) and Nepal (Mool, P.K. et. al 2001) in cooperation with United Nations Environment Programme Regional Resource Centre – Asia and the Pacific (UNEP/RRC-AP) shows the followng salient information to be noted by the water resource manager for flood control in India as these drain into our river systems (Table 4.7.3.2)

TABLE 4.7.3.2

Summary of Glaciers and Glacial Lakes in Bhutan and Nepal

	Glaciers			Glacial	Lakes	
Country	*Number*	*Area (Km^2)*	*Ice Reserves*	*Number*	*Area (Km^2)*	*Potentially Dangerous*
Bhutan	677	1316.71	127.25	2,674	106.776	24
Nepal	3252	5323.89	481.23	2,323	75.70	20

*Source : Mool, P.K. et. al., 2001

Preparation of glacier inventory of the Indian Himalayas is a difficult task as the glaciers occupy trans-national boundaries where aerial photographs are not available for various river catchments. The job can be done by seeking regional and international collaboration

for the purpose so as to make realistic estimations of glaciers feeding the Indian Himalayan rivers. According to the present investigator, probably 50,000 km^2 of glacier area drains into our landmass making Indian Himalayan rivers perennial which support a large population of men and animals. (Bahadur, J., 2002).

4.8 SOIL FORMATIONS

Soils are regarded as an accumulation of loose weathered material by Geologists. The soil depth varies from place to place. Between the soil proper and the bedrock in a layer of shattered and/or partly weathered rock is the *subsoil.* The term *'regolith'* is a convenient one to cover both soil and subsoil. A vertical section through the soil-subsoil-bedrock is termed as soil profile. In the nomenclature of soil scientists (pedologists) the D horizon corresponds to bedrock and the C horizon to the subsoil. The soil proper is divided into an upper A horizon and a lower B horizon, which are further subdivided. The upper part of the A-horizon contains much organic matter and is strongly leached; the lower portion of the A horizon has much less organic matter and has suffered much leaching – the leaching removes mainly Ca, Fe from the soil.The B horizon is largely a zone of deposition of leached material and fine clay and silt particles.

Soil is essentially a mixture, in varying proportions, of organic matter (largely vegetative) called humus and inorganic (mineral) particles derived by weathering of rocks. The inorganic part of a soil may be derived *in situ* or as a result of the transport of debris from elsewhere.

Top soil should be treated as a living system. A table spoon of soil may contain billions of micro-organisms including bacteria, actinomycetes, fungi, algae, most of which are principal decomposers of organic matter. Decomposition results in formation of humus and the release of many plant nutrients. The microbes also produce sticky substances called polysaccharides which glue soil particles together and help soil to resist erosion. Certain bacteria in the soil in the roots of plants convert atmospheric nitrogen into fixed forms of nitrogen that plant and other organizations used to make proteins affecting soil productivity.

To maintain soil health, it must be fed with soil organic materials, such as, manures and crop residues so that the delicate balance between physical, chemical and biological properties is protected and

nurtured to ensure its long-term productivity and stability.

Himalayan soils vary from the rich deep alluvial soils of the terai and bhabar tract to the thin and bare soils of the high mountains and almost desert-like soils of the trans-Himalayan zone. The major soil groups found in the region are *Palehumults* (brown hill soils), *Hapludalf* (submontane soils), *Cryoborolls* (mountain meadow soils), *Lithic Entisols* (skeletal soils), *Paleustalfs, Rhodustalfs* and *Haplustalfs* (red loamy soils) and associations thereof. Members of *Orthents, Fluvents* and *Ochrepts* are also found (Murthy, R.S., Pandey,S, 1978).

Palehumults (brown hill soils) have developed from Tertiary sedimentaries consisting of sandstone, shale and micaceous grey sandstone at altitudes ranging from 600 to 1700 m, having an average rainfall of 800 to 2000 mm. These soils are fairly deep and moderately permeable. The texture varies from loam to silty clay loam. The subsurface horizons are compact and consist of generally grey and dark brown clay loam.

Hapludalf (submontane soils) have developed under unique ecological environment of natural vegetation at high altitudes (deodar, spruce, blue pine, chir etc.), high rainfall and complex geological and geo-morphological formations. The surface layer upto 15 cm consists of dark-brown to dark sandy loam, with loose and undecomposed organic matter, grading to dark brown sandy loam rich in humus at depths ranging from 15 to 50 cm. Generally these soils are acidic. The top layers are siliceous with good and balanced C/N- ratio. These soils have moderate to high inorganic matter but deficient in phosphorous, calcium and zinc.

Members of *Fluvent* are generally found in the valleys. These soils vary from fine sandy loam to loamy course sand and are shallow to fairly deep.

Cryoborolls (mountain meadow soils) are generally found at high elevations, with dry and cold climate and scanty vegetation, mostly alpine pastures. By and large, they range in texture and structure because of admixtures of disintegrated rock fragments, colluvial materials and screes.

Lithic Entsols (skeletal soils) are found confined to the are found confined to the north-eastern part of Ladakh and north-western part of Gilgit in Jammu and Kashmir. The soils are very shallow, overlying the weathered mantle of parent rocks. Owing to deficient precipitation,

poor vegetative cover and the existence of conditions unfavourable to intense weathering, either chemical or mechanical, soil development is limited. If there is any soil cover, it will be badly affected by wind erosion.

Members of *Entisols*, namely *Udorthents* and *Udifluvents*, are commonly found in the higher rainfall areas of the eastern Himalayan tract. They are usually deep to very deep, medium in texture and well drained. They may occur in association with *Ochrept Umbrept* and *Udalfs*.

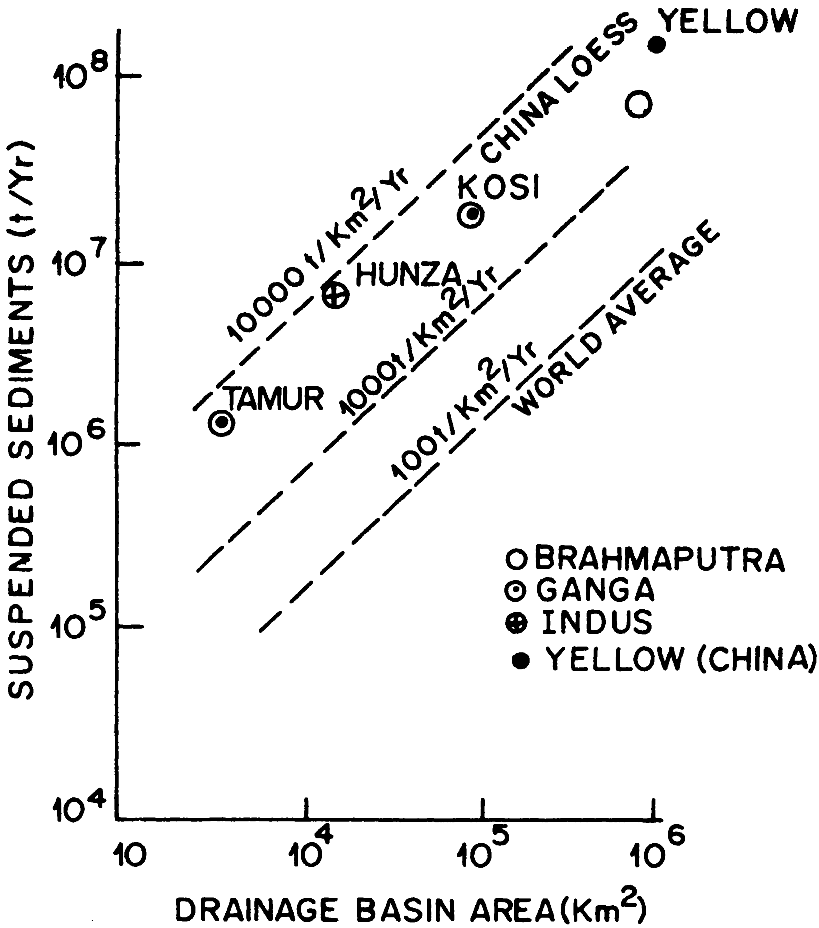
Paleustalfs, *Rhodustalfs* and *Haplustalfs* occur in association with one and another in the upper slopes where the soils are freely drained and create an ustic moisture regime. *Rhodustalfs* are redder than others. *Paleustalfs* and *Haplustalfs* differ only in clay distribution. All these soils, however, have argillic horizon. The soils, in general, are deep, medium to fine textured and slightly acidic. They are generally low in fertility.

Acidity in different proportions is associated with most of the Himalayan soils.

4.9 SOIL EROSION AND SEDIMENT TRANSPORT

Soil erosion includes all processes that result in the physical lowering of the surface of the earth. Surface erosion is the loss of surfacial materials, as a result of action of falling and running water or wind, while mass wasting involves the movement of large masses of fractured bedrock or other unconsolidated materials, including soil from a mountain slope. *Sediment transport* is the movement of the products of erosion through a river system. It is not possible to consider water resource management in the Himalayan region without also considering the sources of the very large volumes of sediment moving annually through the river systems of the region. The limited data of sediment load measurements in Himalayan rivers show that the values for the region exceed the world average (Fig 4.9.1) by almost two orders of magnitude (Ferguson, R., 1984). A central concern in the development or management of water resources of the region is the relationship among land use, on site erosion and sediment transported through the river systems.

Erosion and sediment transport are both processes associated with the work done by water as it moves through the terrestrial portion of the hydrological cycle. This ability to perform work is defined in



THE SEDIMENT LOAD OF SELECTED SOUTH ASIAN RIVERS AS COMPARED TO THE WORLD'S AVERAGE

Fig. 4.9.1 The sediment load of selected South-Asian rivers

terms of power the rate at which work is performed. In simple terms, the amount of work that falling or flowing water is capable of is defined by the kinetic energy of water. The energy in precipitation is related to drop size and depth of precipitation during some defined time period – the precipitation intensity. The ability of that precipitation to promote erosion will depend upon a complex interrelationship among surface soil properties (e.g. infiltration rate, particle cohesion, coefficient of friction, density of vegetative cover,

slope angle). Generally accepted methods to quantify these inter-relationships have yet to be developed as most of the studies on erosion remain highly site-specific and empirical.

The power of flowing water is defined by the depth of flow per unit time and the angle of the slope down which the water is flowing. For water flowing through a channel, it is apparent that an increase and decrease in either stream discharge or slope angle will have the same effect on the power available to cause erosion or sediment transport. In an ideal mountain basin, these factors work in opposition. At points nearest the headwaters, slopes are steep, but stream discharge is low. With increasing distance from headwaters, slope angle decrease, but the stream discharge increases as more tributaries add their runoff to the main channel of the river.

There are a number of natural features of the Himalayan region that cause large quantities of sediment to be delivered to the rivers of the region for transport (Alford, D., 1992). They include :

(i) the glaciated nature of the basin
(ii) the limited natural vegetation cover
(iii) the extreme local relief
(iv) the fractured nature of the rock
(v) the efficacy of freeze – thaw weathering cycle
(vi) the presence of easily – erodable glacier debris
(vii) the frequency and magnitude of landslides, mudflows, and avalanches that deliver sediment to the tributary channel.

The above normal characteristics of the mountain region should be seriously considered as only a few of them are available to modification using traditional environment management practices.

The sediment yield in different tributaries of the Himalayan rivers range from 6.0 to 98.4 m^3/ha/yr as shown (Table 4.9.1)

High erosion diminishes the productivity of arable and non-arable lands, marginalizes the aquatic resources for riverine fisheries and off-farm employment opportunities. Further, deposition of eroded material in the riverbeds reduces the carrying capacity of the rivers and causes floods in the down plains. Out of 40 mha area affected by floods in the country, 24 mha of the worst affected area lies in Indo-Gangetic plains. Besides ensuring adequate vegetative cover, proper gully control, water harvesting structures are to be provided in mini-catchment so as to reduce runoff and sediment yields of the tributaries feeding main river system(Samra, J.S.et.,al.,1999).

TABLE 4.9.1

Soil Erosion in different Tributaries of Major River Systems in Indian Himalayas*.

River systems	*Tributaries*	*Sediment yield ($m^3/ha/yr$)*
	Ramganga	17.3
Ganga	Sunkosi	27.3
	Tamur	60.8
	Bhagirathi	23.5
	Dibang	8.0
Brahmaputra	Teesta	98.4
	Buri Dihang	17.7
	Lohit	34.2
	Pagladiya	31.4
	Chenab	25.2
Indus	Sutlej	6.0
	Beas	15.1

* Source : Das, D.C. et.al (1981); Singh, D.R. and Gupta P.N. (1982) and Valdiya, K.S. (1985).

4.10 NATURAL LAKES SYSTEMS

Both saline and freshwater natural lakes exist in Himalayas. Saline lakes abound in arid region while those lakes which are extremely poor in electrolytes are abundant in humid region, being nurtured by monsoon. These lakes are slanted at altitudes varying from 600m to 5,600 m and are exposed to climatic conditions that vary from cold deserts of Ladakh to wet humid of Manipur. Very few scientific studies are undertaken on these lake ecosystems and the water management programmes are either completely lacking or grossly inadequate (Zutshi, D.P.,1985).

The high altitude lakes have been formed by embankment across the land of drainage by avalanche debris from a side slope or by the advance of a side glacier with its lateral moraine. In general, the catchment area of these lakes have scanty vegetation which is either of scrub type or of some herbaceous species. The size of these lakes vary from less than a hectare to several hundred hectares, having a depth from a few meters to about 100 meters. The exact period of ice cover in these lakes is not very well known but it is generally presumed

that ice melting starts by the end of June and lasts till October. The duration of an ice-free period of four months, i.e. June to October can vary from year to year depending upon local weather conditions. The thermocline was found well developed in many cases but there is no information on the extent of thermal stability. The maximum surface water temperature does not exceed 15°C. The hypolimnion water temperature vary between 6-7°C in shallow water lakes. In some lakes, no thermal stratification was observed and this could be due to cold water flowing from the adjacent glacier. High content of fine glacier silts in lake waters reduces light penetration and limits the depth and productivity of phytoplankton. The lake waters are also relatively poor in nutrient contents but are well oxygenated even at lower depths. Carbonate alkalinity is usually absent in these lakes. The sediment analysis of lake waters show that they are sandy-type and poor in organic carbon. In some glacial lakes trout fish thrive well. Information about catchment, ecological conditions including energy relationships need detailed studies. Most of the lakes are getting heavily silted due to landslide, deforestation and other human activities, needing remedial action for regeneration of their ecosystems and thereby the local environment.

Lake water resources holding cold water fisheries are assessed as follows by National Research Centre on Coldwater Fisheries (NRCCWF, 2000).

Natural Freshwater Lakes	20,000 ha
Brackishwater Lakes	2,500 ha
Man Made Reservoirs	50,000 ha

Amongst 258 fish species identified from Indian uplands, 203 are reported from the Himalayas while 91 are from the Deccan plateau. There has been a drastic depletion in overall fish catch and the size of the fishes and their biomass has shown steady decline due to lack of proper management practices, (See section 5.8 for details on fisheries).

4.11 PERENNIAL RIVER SYSTEMS

The perennial Himalayan river system (Fig 4.11.1) is unique in the world as it forms the largest highland-lowland interactive system. It consists of three major river systems i.e. Indus, Ganga and Brahmaputra whose long term average runoff (Stone, P.B.,1992) is as follows :

TABLE 4.11.1 (A)

Average Runoff of Indus, Ganga and Brahmaputra Rivers*

River Basin	*Measurement Station*	*Average Annual Runoffkm³/yr.*
Indus	Near Arabian Sea	207.8
Ganga	Hardinge Bridge	494.3
Brahmaputra	Bahadurabad	510.4
Total		1,212.5

* Stone, P.B. (1992)

It has been observed that the average specific discharge (water yield per unit area) from the mountain catchment for arid Indus is

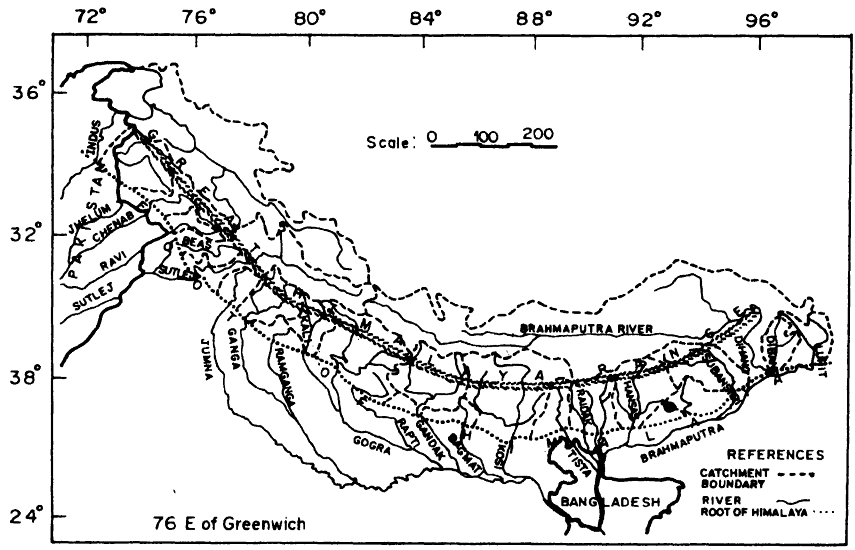


Fig. 4.11.1 Perennial Himalayan River Systems in India

about 3 times the average for the whole river basin; for Ganga, it is twice the average for the whole river basin, but for per-humid Brahmaputra mountain catchment, it is about 10% higher than the average value for the river basin as a whole (Bahadur, J, 1999). These differences are due to the distinctive and differential role played by melt-water contributions from snow and glaciers from high altitude catchments (decreasing from west to east) on one side and the

differential distribution of monsoon rainfall contributions (decreasing from east to west).

Himalayan river systems have catchments in the neighbouring countries. The water resource potential in the river basins of India are assessed (Central Water Commission, 1996) in Table 4.11.1(b)

TABLE 4.11.1 (B)

Water Resources Potential in the River Basins of India*

River Basin	*Average Annual Flow (km³/yr)*
Indus	73.31
Ganga	525.02
Brahmaputra	585.60
Total	1183.93

* Source: Central Water Commission, 1996

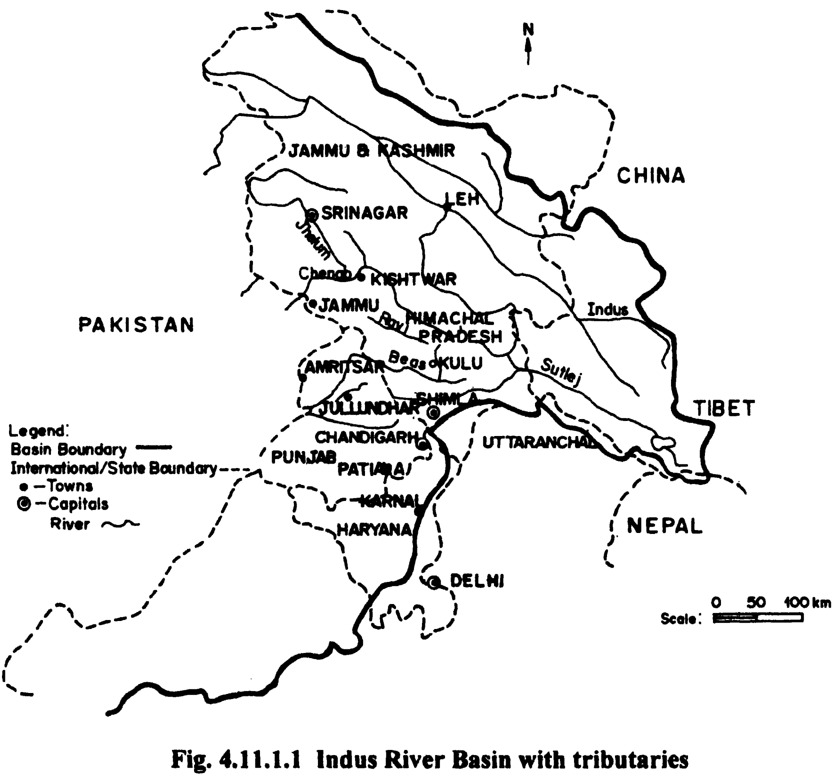


Fig. 4.11.1.1 Indus River Basin with tributaries

The water resources of Indus are taken upto the border with Pakistan and are much reduced as compared to the average annual flow of the combined river discharge in the Arabian sea in Table 4.11.1 (A). The discharges of Ganga and Brahmaputra are enhanced and could be the outcome of effect of global warming contributing excessive melt run-off due to shrinkage of glacier fields. A brief narration of these three basins is given in the following paragraphs:

4.11.1 The Indus River Basin

The Indus river basin (Fig 4.11.1.1) extends over an area of 11,65,500 km^2 and lies in Tibet (China), India, Pakistan and Afghanistan. The drainage area lying in India is 321,289 km^2 (Central Water Commission, 1989) which is nearly 9.8% of total geographical area of the country. The river basin is bounded on the north by the Karakoram and Haramosh Ranges, on the east by the Himalayas, on the west by the Sulaiman and Kirthar Ranges and on the south by the Arabian Sea. The basin lies in the states of Jammu and Kashmir, Himachal Pradesh, Punjab, Rajasthan, Haryana and Union Territory of Chandigarh. The state-wise distribution of the drainage area is given below (Table 4.11.1).

The upper part of the basin lying in Jammu and Kashmir and Himachal Pradesh is mostly mountain ranges and narrow valleys. In Punjab, Haryana and Rajasthan, the basin consists of vast plains which are fertile granary of the country. The principal soil types found in

TABLE 4.11.1

Statewise Distribution of Drainage Area of Indus River Basin

State	*Drainage area (km^2)*
Jammu and Kashmir	193,762
Himachal Pradesh	51,356
Punjab	50,304
Rajasthan	15,814
Haryana	9,934
Chandigarh	114
Total	321,289

* Source : CWC 1989.

the basin are submontane, brown hill and alluvial soils. The cultivable area of the basin is about 9.6 M.ha which is 4.9% of the total cultivable area of the country (Ministry of Water Resources, 1998).

The Indus river originates north of Great Himalayas on the Tibetan Plateau near Lake Manasarovar (5,182 m) and Mt. Kailash. The river flows westward, south of Karakoram range and north of the Great Himalayas, to Mt. Nanga Parbat, where it turns sharply to the south of Lake Pangong and cuts across the main Ladakh range which it pierces again near confluence with the river Shyok. The river takes a sharp bend past the base of the Nanga Parbat massif before flowing into the plains of Pakistan and Arabian Sea after travelling a distance of 2880 km. The length of the river in India is 1114 km. Its principal tributaries are the *Sutlej*, the *Beas*, the *Ravi*, the *Chenab* and the *Jhelum*.

The Sutlej

The river Sutlej rises near the Lake Manasarovar in Tibet. It flows for a considerable distance before entering the Indian territory near Shipki La (Negi, S.S., 1998). Thereafter it drains the trans-Himalayan zone of Spiti, its major tributary. The river Sutlej has cut across the Great Himalayan Range through a deep gorge. Just upstream of this gorge, it is joined by the river Baspa which drains the eastern part of Himachal Pradesh. After crossing the great Himalayan range, the river Sutlej flows in a more or less south-west direction before emerging into the plains near Bhakra.

The Beas

The river Beas is another major tributary of the Indus river. It rises on the southern slopes of the Pir Panjal range just below the Rohtang pass (~ 4000 m). It drains Manali and Kulu valleys cutting Dhauladhar range at Larji. The river gradient from Rohtang massif to Larji is very steep. The main tributaries of the river Beas before it cuts across the Dhauladhar range are:

(i) The Parbati which rises in the snowy waste from Manikaran. It joins river Beas near Shamshi in the Kulu valley.

(ii) The river Harla joins the Beas near Bhuntar.

(iii) The river Sainj which rises in the snows of an off-shoot of the Pir Panjal range that marks the watershed of the Beas and Sutlej rivers. It joins the river Beas near Larji

(iv) The river Tirthan which rises in the snows of an off-shoot of Pir Panjal range and joins the Beas near Larji.

The gradient becomes gentler south of Larji. Thereafter, the river Beas drains past the town of Mandi and takes a westerly course across the southern part of Kangra valley. In Kangra valley, tributaries Uhl, Suketi, Luni, Awa, Banganga, Gaj and Chaki join the river Beas. The river Beas enters the plains of Punjab near Pathankot after cutting across the Siwalik range.

The Ravi

The river Ravi is another important tributary of the river Indus. It rises in a tract between Dhauladhar range in the south and the Pir Panjal in the north. It originates in Bara Bangahal as joint stream formed by the Bhadal and Tant Gari, fed by glaciers. The river Ravi flows in a more or less westerly direction before it cuts across the Dhauladhar range to enter he plains of Punjab. Its main northern bank tributaries are the snow-fed Siul and Baira streams.

The Chenab

The Chenab is another major tributary of the river Indus. It drains parts of north-western and western Himachal Pradesh and the eastern parts of Jammu and Kashmir. It is made up of the rivers Chandra and Bhaga, both of which originate on the north-western glaciated slope of great Himalayan range. Both the rivers flow through sparsely inhabited region. The river flows through the famous Pangi tract of Himachal Pradesh. Its main northern bank tributaries are Saichu and Miyan streams which originate in the snowy wastes of the southern slopes of the great Himalayan range. The river cuts through the Pir Panjal range and crosses over from the north flank to southern part. It flows for a considerable distance along the base of the Pir Panjal range in Kashmir, before entering the plains where it joins the river Indus.

The Jhelum

The river Jhelum is yet another major tributary of the river Indus. It originates from the northern slopes of the Pir Panjal range which girdles the valley of Kashmir. It flows past the center of the valley before cutting through the Pir Panjal range in a narrow gorge from Baramula to Muzaffarabad where it turns sharply towards south making a typical hairpin bend. Its major tributaries are :

(i) The river Liddar which originates in snowy wastes at Chandanwari. It joins the river Jhelum in the central part of the Kashmir valley.
(ii) The river Sind which originates the northern slopes of the great Himalayan range which hems the Kashmir valley. It joins the river Jhelum near Srinagar.
(iii) The river Kishenganga originates in the southern slopes of the great Himalayan range. It drains the north-western part of the Kashmir valley. It has cut across the Pir Panjal range and joins the river Jhelum further downstream.
(iv) A number of small tributaries draining the Kashmir valley also contribute their water to river Jhelum.

4.11.2 The Ganga River System

The Ganga basin (Fig 4.11.2.1) extends over an area of 1,086,000 km^2 and lies in India, Tibet (China), Nepal and Bangladesh (Central Water Commission, 1989). The drainage area lying in India is 861,404 km^2 which is nearly 26.2% of the total geographical area of the country. The basin is bounded on the north by the Himalayas, on the west by the Aravallis and the ridge separating it from Indus basin, on the south by Vindhayas and Chhotanagpur plateau region and on the east by the Brahmaputra ridge. The basin lies in the states of Uttranchal, Uttar Pradesh, Madhya Pradesh, Bihar, Rajasthan, West Bengal, Haryana, Himachal Pradesh and the Union Territory of Delhi. The state-wise distribution of the drainage are given below :

TABLE 4.11.2.1

State-wise Distribution of the Drainage Areas of Ganga River*

State	*Drainage Area (km^2)*
Uttaranchal	51,124
Uttar Pradesh	243,240
Madhya Pradesh	198,962
Bihar	143,961
Rajasthan	112,490
West Bengal	71,485
Haryana	34,341
Himachal Pradesh	4,317
Union Territory of Delhi	1,487
Total	861,404

* Source : CWC, 1989

The main physical divisions are the northern mountains, Gangetic plains and the central highlands. Northern mountains comprises the Himalayan ranges including their foot hills. The Gangetic plains, situated between the Himalayas and the Deccan plateau, constitute the most fertile plains of the basin ideally situated for intensive cultivation. The central highlands lying to the south of the Great plains consists of mountains, hills and plateaus intersected by valleys and river plains. They are largely covered by forests. Aravalli uplands, Bundelkhand upland, Malwa plateau, Vindhyan ranges and Narmada valley lie in this region.

Predominant soil types found in the basin are sandy, loamy, clay and their combinations such as sandy loam, loam, salty, clay loam and loamy sands. The cultivable area of Ganga basins about 57.96 M.ha which is 29.5% of the total cultivable area of the country.

The Ganga river basin parallels the long axis of the Himalayan range from the headwaters of Himachal Pradesh, right from the eastern slopes of the Shimla ridge to eastern Nepal. The course of the river has not been determined by down cutting the erosion, throughout much of its length, but rather by the down-warping of the crust in the "subduction zone" to the south of the tectonic uplift of the Himalayas.

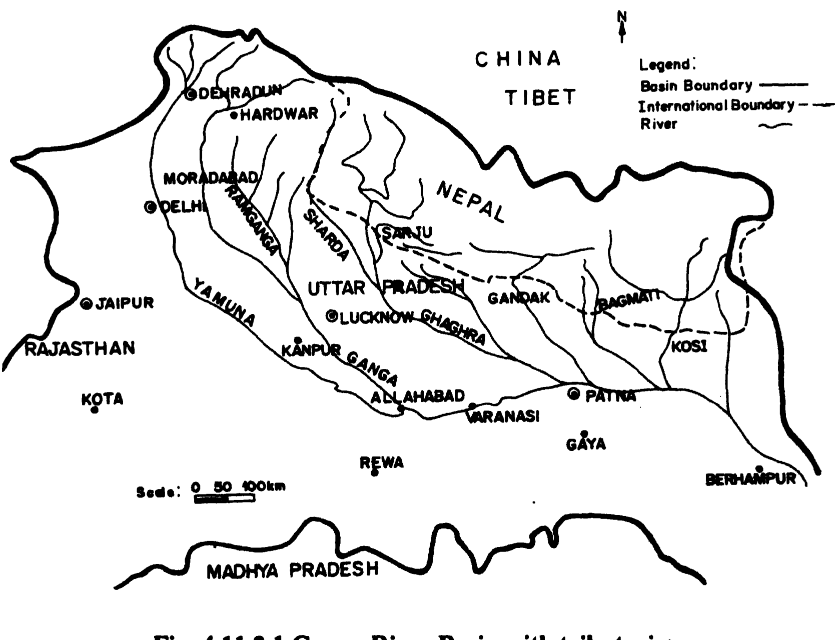


Fig. 4.11.2.1 Ganga River Basin with tributaries

The Ganga originates as Bhagirathi from the Gangotri glacier (4000-5600 m) surrounded by mountain peaks of over 7000 m. The Bhagirathi is joined by Alaknanda at Deoparyag and the combined stream is known as Ganga. It debouches into plains at Rishikesh. It is joined by a number of tributaries on both the banks in the course of its total run off 2525 km. before it outfalls into the Bay of Bengal. Its major tributaries are *Yamuna, Bhagirathi, Alaknanda, Kali, Ramganga, Ghagra, Gandhak* and *Kosi* (Ministry of Water Resources, 1998).

The Yamuna

The river Yamuna is the largest tributary of the Ganga river system. It drains the western-most part of the Ganga basin. It rises from Yamunotri glacier in Uttarkashi district lying on the south-western slope of the Bandrapunch peak. It flows for a considerable distance along a SW direction up to the base of Mussorie ridge after which it turns towards west. The following are the main tributaries of the Yamuna river system:

(i) The river Tons rises in the snows beyond the valley of Har-ki-dun. It is made of two main rivers, the Rupin and the Supin. The river Tons then drains in a SE direction joining with the river Yamuna at Naugaon.

(ii) The river Algar drains the northern slopes of the Mussorie ridge.

(iii) The river Giri drains the south-eastern corner of Himachal Pradesh. It flows past the base of the Shimla ridge which marks the water-divide of the Indus and Ganga catchments. The river Giri then flows in a SE direction, through Sirmur and past Renuka before joining the river Yamuna near Paonta.

(iv) The river Bata originates in the lower slopes of the Nahan ridge. It flows through the Paonta valley in the easterly direction before joining the river Yamuna.

The Bhagirathi

The river Bhagirathi rises from the south of the Gangotri glacier at the base of the Chowkhamba peak (7138 m). Thereafter, it flows in a SW, S and E direction past the towns of Uttarkashi and Tehri to merge with the river Alaknanda at Deoparyag to be called Ganga.

The river flows through a narrow gorge before emerging into the plains after cutting across the Siwalik hills near Hardwar. The river Bhilangana is the largest tributary of the river Bhagirathi. It rises from Kathling glacier (3800-6500 m)to the NE of Tehri and drains through a narrow river valley to join the river Bhagirathi near Tehri.

The Alaknanda

The Alaknanda river rises from the glaciers to the north of the temple town of Badrinath. It traverses through the towns of Vishnuparyag, Nandparyag, Karanparyag, Rudraparyag and Srinagar. The main tributaries of the river Alaknanda are Mandakini, Pindar, Nandakini, and Dhauliganga.

(i) The river Mandakini rises from the snowy wastes of the Bhagirathi Kharak and Satopanth glaciers to the east of Kedarnath. It is the highest tributary of the Alaknanda river.

(ii) The river Pindar rises from the Pindari glacier on the western slopes of the Alaknanda-Kali water-divide. It flows in a more or less westerly direction before joining the Alaknanda river at Karanparyag.

(iii) The river Nandakini is another important tributary of the Alaknanda. It flows along a SW direction before joining the main river at Nandparyag.

(iv) The river Dhauliganga rises from the snowy wastes on the southern face of the great Himalayan range. The river Puspawati, draining the valley of flowers is one of its main tributaries.

The Kali

The Kali river forms the border between India and Nepal. It flows in a SSW direction. There are two headwaters of this river viz. (i) Kalapani, the eastern headwaters which is a collection of springs and (ii) Kuthi Yankti, the western headwaters which is born in the snow fields of the Himadri on the southern slopes of the great Himalayan range. Kali's main tributaries are :

(i) The river Goriganga, rising from the eastern snowbound slopes of the Alaknanda-Kali water-divide. It flows in South-Eastern direction and is joined by a number of tributary streams before it merges with the Kali river at Jauljibi in eastern Kumaun.

(ii) The river Sarju is another important tributary of the river Kali. It drains central Kumaun and is composed of a network of tributary streams. It is joined by a rivulet known as the Ramganga, before it merges with the Kali at Pancheshwar. The river Sarju is the largest tributary of the river Kali.

(iii) The river Ladhiya rises from a number of spring-fed streams in the south-eastern corner of Kumaun. It drains a relatively smaller area before joining the river Kali.

(iv) The river Lohawati is another small tributary which joins the Kali river in the south-eastern Kumaun.

(v) A number of tributaries join the river Kali from eastern flank (from Nepal).

The river Kali enters the plains at Baramdeo and further downstream it is known as the river Sarda. It flows into the river Ghagra in the plains of Bihar.

The Ramganga

The river Ramganga drains parts of south-western Kumaun. It is formed by a number of streams which join the main stream that drains through a V-shaped valley, past the broad terraced fields of Ganai and through the dense foothill forests of Corbett National Park to enter the plains downstream of Dhikala. Its waters flow into the river Ganga in the plains of Uttar Pradesh.

The Ghagra

This river drains western Nepal. Its tributaries are:

(i) Karnali is the largest river draining into Ghagra. It rises in the springs of Mapche Chungo south of Mansarovar in Tibet. Thereafter, it flows south of the Gurla Mandatta, cuts across the great or main Himalayan range to enter Nepal. The river Karnali receives water from a large number of snow-fed and spring-fed tributaries in western Nepal. It flows for a considerable distance along a southerly direction before it turns towards South-west and once again towards South-east before joining Ghagra.

(ii) The river Seti rises near Api. It flows in an easterly direction to join the Karnali.

(iii) The river Bheri rises in the snows of the Dhaulagiri massif. Its waters drain into the main stream in the lower hills of Nepal.

(iv) The river Ghagra or the Girwa pierces the lower hills near Gaindakanda to enter the plains of Bihar.

The Gandak

The Gandak river system drains central Nepal. It joins the river Ganga in the plains. The main river of the Gandak river system is the Kali or the Krishna Gandak. It rises in the trans-Himalayan tract beyond Manang Bhot. The river cuts across the great Himalayan range through a spectacular gorge between the Dhaulagiri and the Annapurna massifs.

The important tributaries of the Gandak are :

(i) The river Seti Gandak which rises from the base of the Annapurna Himal massif. It drains the famous Pokhra valley before joining the main stream.

(ii) The river Marsiandi flows north of the Annapurna massif and turns south in the tract between it and the Manaslu.

(iii) The river Trisuli rises from the Ganesh Himal. The river cuts across the lower hills and flows through the thickly forested chitwan valley to enter the plains in India.

The Kosi

The Kosi river system drains eastern Nepal. It is also known as Sapt Kosi in its upper reaches as it is formed by seven main rivers. These are :

(i) The Sun Kosi, which rises beyond Gosaithan massif.

(ii) The Indrawati, which drains the eastern outer rim of Kathmandu valley.

(iii) The Bhola Kosi which drains the snowmelt waters of Cho-Oyu and the Gauri Shankar massifs.

(iv) The Dudh Kosi which drains the Mt. Everest massif, the highest peak in the world.

(v) The river Arun which rises in the trans-Himalayan zone of Tibet. It has cut across the main Himalayan range through a fantastic gorge to the east of the Everest massif.

(vi) The river Barun rising from Barun glacier at the base of Makalu, the fourth highest peak in the world. It drains into the river Arun.

(vii) The river Tamur is the easternmost tributary. It rises from the snows on the western flank of the Kangchenjunga group

of peaks known as the Kumhakaran Himal. The river Kosi then flows towards south to emerge from the hills through he Chatra gorge.

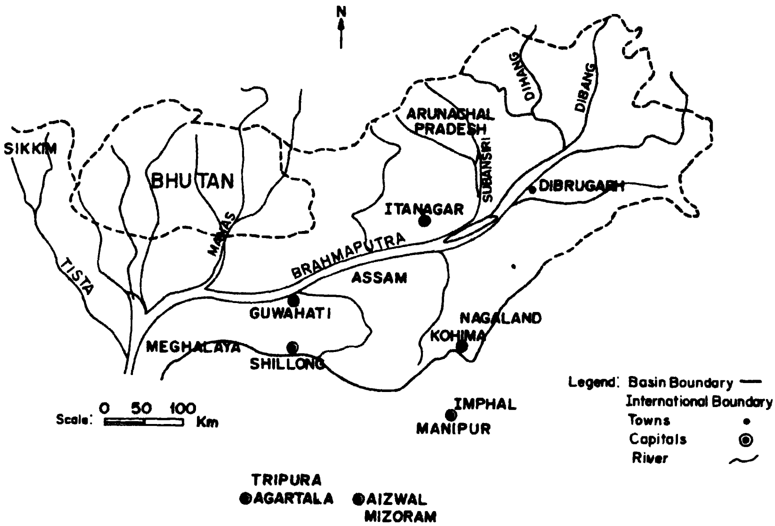


Fig. 4.11.3.1 Brahmaputra River Basin with tributaries

4.11.3 The Brahmaputra River Basin

Brahmaputra basin (Fig 4.11.3.1) extends over an area of 580,000 km^2 lying in Tibet (China), Bhutan, India and Bangladesh. The drainage area lying in India is 199,413 km^2 which is nearly 5.9% of the total geographical area of the country. It is bounded on the north by the great Himalayas, on the east by the Patkari range of hills running along the Assam – Burma border, on the south by the Assam range of hills and on the west by the Himalayas and the ridge separating it from Ganga basin. It lies in the States of Arunachal Pradesh, Assam, Nagaland, Meghalaya, West Bengal and Sikkim. The state-wise distribution of drainage area is given in Table 4.11.3.1

The upper portion of the river basin, lying in Arunachal Pradesh and Nagaland, consists mostly of mountain ranges and narrow valleys. Most portion of the basin, lying in Assam, Meghalaya and West Bengal, consists of hills, forests and tea gardens. The Cooch Bihar and west Dinajpur districts of West Bengal has fertile plains.

The most predominant soil type in the basin is red loamy and alluvial soil. The other important soil types are sandy, loamy, clay

soils, their combinations and laterite soils. The cultivable area of the basin in about 12.15 M ha which is 6.27% of the cultivable area of the country.

TABLE 4.11.3.1

State-wise Distribution of the Drainage Areas of Brahmaputra River

State	*Drainage Area (km²)*
Arunachal Pradesh	81,424
Assam	70,634
West Bengal	12,585
Meghalaya	11,667
Nagaland	10,803
Sikkim	7,300
Total	1,94,413

The Brahmaputa is known as Tsangpo in Tibet , the Siang or Dihang in Arunachal Pradesh and the Jamuna in Bangladesh. The headwaters of Brahmaputra (Yalu Zangbu or Tsangpo) river system are immediately adjacent to those of Indus river, north of the Greater Himalayas. The river rises in the glaciers of the Kailash range, just south of the Lake Kangg yu Tsho in Tibet. It flows in an easterly direction. The 2880 km long Brahmaputra traverses its first 1,625 km in Tibet, the next 918 km in India and the remaining 337 km in Bangladesh. The average width of the Brahmaputra is about 86 km of which the river itself occupies 15-19 km (Ministry of Water Resources, 1998). The river forms almost a trough receiving the flows both from north and south. Some of the important tributaries of the river in India are the Dibang, the Luhit, Subansiri, the Manas, the Sankosh, the Teesta, the Dhansiri and the Champamati. Throughout its course in India, the Brahmaputra is highly braided with some well defined and stable banks where the river width is narrow. All along its course, abandoned wet lands and back swamps are common. Because of friable nature of the hills in its catchment, high intensity of rainfall and seismicity of the area, the river carries heavy sediment load of the order of 735 million tones per annum.

The main river systems draining into Brahmaputra which rise from various parts of the eastern Himalaya are :

The Teesta

The Teesta river system drains the Darjeeling hills and Sikkim. It rises from the Zemu glacier on the eastern slopes of Kangchenjunga massif. Thereafter it flows along a southerly course before merging with the Brahmaputra in the plains of Bengal. The Teesta falls sharply within a few kilometers of its source in the Zemu glacier dropping to an elevation of about 1000 m near Singhik and Mangan in central Sikkim. The deep gorge of the river Teesta divides the hills of Darjeeling into two parts – the Darjeeling-Tiger hill range in the west and the Kalimpong hills to the east. The main tributaries of the river Teesta are :

(i) The Lhonak river rising from the snowy wastes of north Sikkim.
(ii) The river Lachung rising from Pauhnri and joining the Teesta at Chumthang.
(iii) The Ranjit river which is a large tributary of the Teesta river is fed by glaciers on the southern slopes of the Kangchenjunga massif.

The Manas

The Manas river system drains parts of central and eastern Bhutan. The main river rises in the southern slopes of the main or great Himalayan range in the north eastern part of Bhutan. One of its streams also rises in Tibet and cuts across the main Himalaya. It flows in a SSE- direction and then makes a gradual turn towards South-East near Tashi Ganga. The main tributaries of the river Manas are :

(i) The river Mangde Chhu is draining central Bhutan. It flows in a south-east direction before joining the Manas just before the main river enters the plains.
(ii) The river Chamke also rises from the snows on the southern slopes of the main Himalayan range. It flows past Bumthang to join the river Mangde chhu.
(iii) The river Kurd is another important tributary of the river Manas. It flows towards south before joining the main river.

4.12 MAN-MADE WATER RESERVOIRS

About 60% of the country's water resources are available in the Himalayan river basins. There is, however, a great variability, in space and time, for the water availability. Hence, building up storage

reservoirs becomes essential for a variety of uses, such as, irrigation, hydropower generation, domestic and industrial requirements, flood moderation etc.

Storage capacities evaluated till 1993 is given (Table 4.12.1) which shows that only 14.2% of the average flow of water has so far been planned to be stored in the Himalayan region (Central Water Commission, 1996). Additional storages will be needed for consistent and assured water supplies to the inhabitants of the mountain region and the associated plains.

TABLE 4.12.1

Water Resource Storage and Projects in the Himalayan Region

S. No.	*River System*	*Average Annual flow*	*Live Storage Capacities*				*Percentage of likely storage to Average Annual Flow*
			Completed Projects	*Projects under construction*	*Total*	*Projects under consideration*	
1.	Indus	73.31	13.82	2.45	16.27	0.27	23
2.	Ganga	525.02	37.84	17.06	54.90	29.56	16
3.	Brahmaputra & Barak	585.60	1.09	2.40	3.49	63.35	11
	Total	1183.9	52.75	21.91	74.6	93.18	14.2

* Source: Central Water Commission, New Delhi, 1996.

Likely storage to average annual flow for Indus, Ganga and Brahmaputra being 23, 16 and 11 per cent respectively leaving a substantial scope for additional development of water resources of these river systems.

It is worth noting that the land/water linkages are generated by a number of different processes which has to be considered for creation of water storages and their management for sustainable development.

Rainwater partitioning between the vertical return flow and the horizontal flow which recharges aquifers and rivers is determined by the interaction of rainwater with soils and vegetation. This partitioning takes place both at the soil surface between the surface runoff and

infiltration and in the root zone between root uptake and percolation to the groundwater.An altered vegetation patterrn and altered soil permeability may both affect partitioning patterns.

Water as a solvent. Chemically reactive and continuously on the move, water easily catches and carries anything solvable from the atmosphere, the soil, surface and the root zone to groundwater and rivers, lakes and coastal waters.

*Societal use.*After it has been used for industry, agriculture or households, water always returns to natural systems with a load of pollutants it has picked up along the way.

Erosive capacity. Water is particularly erosive in specific size intervals of soil particles. Erosion is a severe and widespread problem throughout the tropics.and in the Himalayan region.

Soil fertility is directly linked to water due to its effects on the dynamics of soil organic matter and deep soil weathering. The water-holding capacity of soils depends on such factors as its structure and organic content and is hydrologically very significant.

Pore water in soil forms a link between soil drainage, due to groundwater decrease and the soil cover and land surface. In vulnerable soils, not only groundwater over-exploitation, but also drainage works may cease considerable land subsidence. Normally the above aspects are not seriously considered by water resource planners and engineers and we all face problems of water quality and quantity.

4.13 SPRINGS, SUBSURFACE FLOW AND GROUND WATER

Excessive deforestation has marginalized perenniality of springs, subsurface flow and groundwater recharge. Studies have indicated diminishing discharge from snow-melt and glacier-melt contributions, leading to dwindling capacities of lakes, rivers and reservoirs (Rawat, J.S. 1988, Vaidya, K.S. and Bhartarya, S.K., 1991; Rao, K.S. and Saxena, K.G., 1994). This has aggravated the drinking as well as irrigation water over the years. High seepage losses (300-400 litres/ day /500m^2 of wetted area), meager lean flow, predominance of rainfed farming and low level of electrification in the region are the other associated problems (Srivastava, R.C. et al 1988). Regeneration of perennial flows by rehabilitating mine-spoiled and landslide prone watersheds has been observed at Shastradhara (Juyal, G.P. et. Al 1994) and Nalota Nala (Sastry, G et al, 1997).

An apparent abundance of surface water and topographical limitations in the region have put the utilization process of replenishable ground water at a low ebb. Recent studies indicate that the region has 0.73 m ha m replenishable groundwater resources, which is about 1.7 per cent of the total groundwater potential in the country (Govt. of India, 1998). It is estimated that about 85 per cent of it can be used for irrigation purposes, but only 4 per cent has so far been utilized due to the harsh topographical conditions in the region. There is wide variation in the utilization of groundwater potential in different states and the utilization is negligible in the NEH–region as illustrated by the table 4.13.1

TABLE 4.13.1

Groundwater Resources and Utilization in the Indian Himalayas*

States	*Replenishable groundwater*	*Utilizable Potential for (000,ha m)*	*Current Utilization irrigation (000, ha m)*
North-Eastern Himalayas			
Arunachal Pradesh	143.9	122.3	-
Meghalaya	315/4	268/1	Negligible
Manipur	54.0	45.9	Negligible
Nagaland	72.4	61.5	Negligible
Tripura	66.3	56.4	3.3
Total	652.0	554.2	3.3
Western Himalayas			
Himachal Pradesh	36.6	29.3	18.1
Jammu & Kashmir	44.3	37.6	1.3
Total	80.9	66.9	8.6
Total Himalayas	732.9	621.1	4.0
All India	43,147.7	36,073.	631.9

*Government of India, 'India 1998' (1998).

Chapter 5

BIOSPHERIC ASPECTS

5.1 INTRODUCTION

Biosphere is broadly defined as the sum total of all organic life living on or in the surface of the Earth. It denotes those parts of the Earth where the life exists, they comprise the lower parts of the atmosphere, the hydrosphere and the Earth's crust in contact with these (WMO,1992). Biospheric aspects of the Himalayan region assumes particular importance due to its unique, fragile, and sensitive characteristics of a high altitude environment.

Biogeographically, the Himalaya is a complex region. A sharp and distinct contrast characterizes the eastern (i.e. warm and humid) and the western (cold and arid) conditions with a blend of these elements in the central region. The whole region has been divided into five biotic provinces (Table 5.1.1) under two bio-geographical zones Boreal and Indo-Malayan (Dhar,U.,1996).

TABLE 5.1.1

Distribution of Representative Political Boundaries within Biotic Provinces of the Indian Himalayas *

S. No	*Biogeographic provinces*	*Political boundary*	*Area (Km^2) Area (%)*	*Total*
1.	Trans Himalaya	Jammu and Kashmir, Himachal Pradesh	186,200	44.07
2.	North-west Himalaya	Jammu and Kashmir, Himachal Pradesh	69,000	16.33
3.	West Himalaya	Hill districts of Uttaranchal (Kumaon and Garhwal)	72,000	17.04
4.	Central Himalaya	Sikkim and North Bengal (West Bengal)	12,300	2.91
5.	Eastern Himalaya	Arunachal Pradesh	83,000	19.04

*Source: Rodgers and Panwar (1988)

The West Himalaya biotic province supports a cold and drought resistant vegetation dominated by conifers (chirpine, blue pines, deodar, fir and spruce), legumes, grasses and composites. The Eastern Himalayan flanks harbour a wet humid sub-tropical vegetation rich in magnolias, oaks, laurels, terminalias, rhododendrons, epiphytes, orchids and ferns.

5.2 PASTURES AND GRASSLANDS

Pasture is defined as grazing land that is managed to provide appropriate yield in terms of quantity and sometimes quality of herbs and grasses. *Grasslands* are biomes dominated by herbaceous species in which grasses *(Poaceae)* or sedges (*Cyperaceae)* are abundant, accompanied by forbs, which account for the highest proportion of plant species found in grasslands, with sometimes scattered shrubs and trees. Grasslands can be classified as natural, semi-natural and artificial (Coupland, R.T., 1979). Natural grasslands occur where environmental factors prevent or suppress tree and shrub growth. Most often this is due to climate particularly aridity, on coasts and mountains exposed to salt-laden or freezing winds. Some grasslands occur due to pedological factors, including shallow iron pans, salinity or alkalinity and heavy metals or other phytotoxins. In areas of active deposition or erosion, as along natural river courses, geomorphological processes create natural seral grasslands. Wild herbivores and natural fires are thought to have played a supplementary role in maintaining the area of natural grasslands.

Semi-natural grasslands are found where deforestation and grazing has created landscapes for colonization by species of naturally open habitats, such as, natural grassland and cliffs. These occur in the wet and dry forest zones of the world and in many forest zones such grasslands now exceed the area of natural forest.

Artificial grasslands are manipulated through fertilizer and herbicide application, as well as reseedings to favour a few commercially desirable forage species, particularly ryegrass and white clover.

Natural grasslands have been extensively destroyed by cultivation, and most of those remaining are modified by grazing of domestic animals and the introduction of alien plant species. Most temperate grasslands of all types are modified by agrochemicals.

Agro-ecological and micro-environmental diversity of the Indian

Himalayas have produced a spectrum of rangeland ecologies (Samra, J.S. et al 1999).The elevation of pastures and grasslands ranges from 300 to 4500 m, traversing sub-tropical, temperate and alpine environment. According to edaphic and micro-climatic conditions, these temperate pastures can be categorized as dry rangelands (1800-2000 m), humid range lands (2400-3200 m) and sub-tropical and alpine pasture lands (above 3200 m). The constraints in each zone are specific as described below :

(i) Dry range lands consist of mixed sub-tropical and temperate vegetation. Heavy grazing pressure coupled with water stress in the rhizosphere through most of the year and subsequent soil erosion owing to heavy rainfall events during rainy season leads to extreme degradation of these grasslands.

(ii) Lush green pastures from May to September are visualized in the humid range- lands. A cool climate and adequate moisture in the rhizosphere help to produce good vegetative cover. These grasslands are deteriorating in terms of quality and quantity due to overgrazing and poor management.

(iii) Semi-arid and arid pastures are present in the rain shadow region of the inner Himalayas.Low fertility of soil, water stress, predominance of bushes and high grazing pressure are the major impediments to enhance productivity of these lands.

(iv) Alpine grasslands and meadows account for an area of 1,14,250 Km^2 in the Indian Himalayas.These are characterized by cool summer (15-20°C) followed by heavy monsoon rains (1000-2000 mm) and cold winter (-8 to -20°C) followed by heavy snowfall (2-5 m). They remain snowbound from November to April and open for grazing to sheep, goats and other animals from May to September. Over and unregulated grazing, and poor soil health are the major bottlenecks in increasing the productivity of these pastures.

Himalayan region needs special attention so far as the forage needs of the vast animal population of the area are concerned. The lambing periods may be adjusted so as not to create any stress on the pastures during a part of the year and save the areas from overgrazing and misuse. Thus the nomadic grazing may serve as a great balancing

factor in the proper utilization of the natural herbage resources in the hills and valleys, provided it is properly regulated.

The floristics of the grass cover in the Himalayan region seems to be much better known than any other aspect of its structure and function (Singh, J.S. and Saxena, A.K., 1978). As expected, more and more temperate grasses (C_3-species) come up with increase in the altitude. Practically nothing is known about the productivity and carrying capacity of the grasslands. The production strategy at different altitudes in relation to the canopy architecture and grazing intensity is yet to be investigated. Several grasses have been analysed for chemical composition, but the relation of the latter with the phenology, water stress and grazing frequency is not known. The water-use-efficiency and the energy-capture efficiency of the grass cover have not been worked out, neither is anything known about the nutrient cycling in these grasslands.

A number of exotic species have been tried but the detailed eco-physiological studies on them are lacking. Such studies are necessary with a view to determining their adaptational features and growth requirements of the exotics.

There seems to be a need for long-term coordinated, integrated and inter-disciplinary research performed simultaneously in different eco-climatic zones for scientific management of Himalayan grasslands.

5.3 FORESTS

Forestry concerns the interaction of trees, woodlands, or forests with people. It comprises both practice and theory – the management of forest resources for a specific purpose and the scientific study of forest eco-systems, including all aspects of their management. The term 'woodland' and 'forest' refer primarily to smaller and larger areas of tree-dominated land respectively although they can refer to specific type of forest cover.

Based on forest classification, following forest types are found in the Himalayan region. Area covered by each forest type is given in table 5.3.1 (Champion, H.G. and Seth, S.K., 1968). Tropical wet evergreen forests is distributed mostly on the extreme east on the northern bank of the Brahmaputra valley and heavy rainfall areas of Balipara Frontier Tract. It occurs at 200 m ascending valley to 800 m. Soil is well drained, deep and porous. Important species are *Mesua,*

Kayea assamica, Ailanthus grandis, Pterospermum spp, Quercus lamellosa, Echinocarpus, Michelia doltsopa, Terminalia chebula, Dendrocalamus hamiltonii etc.

TABLE 5.3.1

Area Coverage of Forest Types in Himalaya*

S. No	*Forest types*	*Geographical Area (sq km)*	*Coverage (percentage)*
1.	Tropical wet evergreen forests	13613	3.2
2.	Sub-tropical dry evergreen forests	6086	1.4
3.	Montane wet temperate forests	22582	5.3
4.	Tropical dry deciduous forests	10677	2.5
5.	Himalayan moist temperate forests	54079	12.7
6.	Himalayan dry temperate forests	3577	0.9
7.	Tropical moist deciduous forests	1228	0.3
8.	Sub-tropical Pine forests	62246	14.7
9.	Sub-alpine & alpine forests	248933	59.0
	Total	423021	

*Source: Champion, H.G. and Seth, S.K., 1968

Sub-tropical dry evergreen forests are found mainly in Himachal Pradesh and overlap considerably with Chir pine forests. Two sub-types in this category are *Olea cuspidota* scrub forests and *Acacia modesta* scrub forests.

Montane wet temperate forests occur mostly in Sikkim and Darjeeling district of West Bengal. Important species are *Quercus lamellosa, Q. pachyphylla, Michelia cathcartii, Castanopsis tribuloides, Quercus fenestrata, Acer campbellii, Taxus baccata, Arundingria spp. etc.*

Dry sal-bearing forests (Type-tropical deciduous forests) are found locally in Himachal Pradesh and extensively in Siwalik Hills of Uttaranchal. Common associates of Sal *(Shorea robusta) are Anogeissus latifolia, Buchanania lenzan, Terminalia tomentosa, Diospyrous tomentosa, Acacia catechu, Schleichera oleosa*, etc.

Himalayan moist temperate forests is among the major forest types found in Himalayan region. It is distributed over Jammu and Kashmir,

Himachal Pradesh, Uttaranchal, Sikkim and Bengal. The altitude ranges from 1500 m to 3300 m . Rainfall varies from 1580 mm onwards. Conifers prevail in this type, the chief genera being *Abies, Cedrus, Picea, Tsunga* and *Pinus. Cupressus* and *Taxus* also occur. Among the broad-leaved trees, the *genus Quercus* with several species is the main one and its common associate is *Rhododendron*. Members of *Lauraceae* are frequently seen. *Arundinaria* and related genera of dwarf bamboos are very typical of this forest type.

Himalayan dry temperate forest occur mainly in Kashmir (Ladakh), Himachal Pradesh (Lahaul, Chamba, Bashahr), Uttaranchal (inner Garhwal), Sikkim and part of Arunachal Pradesh. The altitude range is from about 1700 m upwards. Snowfall is important in this type of forest for providing moisture because of low rainfall. This forest type is predominated by conifers, important species being *Cedrus deodara, Pinus gerardiana, Juniperus, Abies and Pinus wallichiana,* Broad-leaved trees include *Acer, Fraxinus* and *Quercus.*

Tropical moist deciduous forests are found in Kurseong area of West Bengal and Uttaranchal. Sal bearing forests constitute the main forests of this type. It occurs mostly on Nahan sandstone with light soil. Important species are *Terminalia bellirica, T. tomentosa, Lagerstroemia parviflora, Tetrameles nudiflora, Cedrela spp., Mallotus philippensis, Dendrocalamus hamiltonii, Bauhinia vahlii, B. purpurea, Sterculia villosa* etc.

Sub-tropical pine forest are distributed generally at appropriate altitudes on the Siwalik hills from Jammu to Uttaranchal and Arunachal Pradesh. *Pinus roxburghii* constitute the characteristic species of Himalayan Chir pine forests. Other important species are *Ficus roxburghii, Quercus icana, Rhododendron arboreum, Syzygium cumini, Myrica spadia etc.*

Sub-alpine and Alpine forests constitute the major part of the Himalayan forests and extend from Kashmir to he Eastern part of Arunachal Pradesh. The altitude varies from 2,900 m to 3500 m but may even go higher up in the West Himalaya. Snow is regular feature and is the source of moisture as the rainfall is low. The tallest trees are typically conifers usually *Abies*. Other common genera are *Juniperus, Pinus, Picea, Mong* etc. Among the broad-leaved, the common trees are *Quercus semecarpifolia, Betula utilis, Rhododendron campanulatum, Taxus baccata, Prunus padus, Strobilanthes atropurpureus, Smilax vaginata, Ribes spp.* etc.

As is evident from the variety of forest types occurring in this region and its extensive forest cover, the region has a very vital impact not only on the climatic and ecological conditions of the country but also has strong influence on the economical and socio-cultural conditions of India. Unabated illegal/commercial fellings, practice of shifting cultivation, soil erosion, wind erosion etc. have resulted in severe deterioration of the eco-climate of the Himalaya. The Government of India has taken up a variety of measures for checking environmental degradation of the Himalaya, but still a lot more is required to be done particularly by the local inhabitants through joint-participatory forest management, by giving up shifting cultivation and taking up other appropriate measures for the conservation of the mountain region.

Although the Himalayas essentially fall into the temperate region, the climate varies from nearly tropical to subtropical, temperate and then to alpine and arctic conditions with permanent snow in the entire northern belt at higher altitudes. In temperate regions, diversity within forests is far less than in the tropics. In tropics, each tree is a mini-eco-system laden with epiphytes, ants, and other micro – and macro – biota. There are fewer species of shrubs and trees in the temperate region (Khoshoo, T.N.,1996). The species composition change in response to altitude in Himalayas. Furthermore, in temperate regions, one species is often dominated and occupies vast stretches horizontally. Thus, we have almost pure natural stands which may appear as a 'monoculture'. However, it is not so because there is a tremendous genetic diversity within each stand.

According to the Forest (Conservation) Act of 1988, 60 per cent of land area in the hills should be under forest cover, while for the country as a whole it should be 33 per cent. The dense forest cover (more than 40% crown density) for the country as a whole is only 11.71 per cent. However, dense forest cover for the Himalayan belt is only 21.78 per cent, but it ranges from 4.9 per cent in Jammu and Kashmir to 65.13 per cent in Arunachal Pradesh as shown in the Table 5.3.2.

From the Table 5.3.2, it is apparent that Arunachal Pradesh is the only state touching the requirement of 60 per cent. Hence, a concerted effort is needed to reforest as great an area as possible, keeping in mind constraints such as excessive grazing on account of a livestock population which is beyond the carrying capacity; escalating human

TABLE 5.3.2

Dense Forest Cover in Himalayas (in km²)*

S. No	*State*	*Geographical Area*	*Dense Forest Cover (>40%)*	*Percentage*
1	Jammu & Kashmir	222,235	10,986	4.9
2	Himachal Pradesh	55,673	8,911	16.0
3	Uttaranchal	51,125	17,448	34.12
4	Sikkim	7,096	2,403	38.86
5	West Bengal (Hill district)	3,149	1,109	35.2
6	Assam	78,438	15,842	20.19
7	Arunachal Pradesh	83,743	54,542	65.13
8	Nagaland	16,579	3,531	29.29
9	Meghalaya	22,429	3,305	14.73
10	Manipur	22,327	5,309	23.77
11	Tripura	10,486	1,825	17.04
12	Mizoram	21,081	4,279	20.29
	Total	*594,361*	*129,490*	*21.78*

*Source: Anonymous, 1993.

population; increasing demand for firewood and small timber and poles far in excess of the mean annual increment; shifting cultivation in the north-eastern sector, resulting in unscientific management.

The importance of forest cover (forests being the abode of most but not all biodiversity) cannot be underestimated, because it is interlinked to long-term ecological security. Furthermore, there is a deep inter-connection between forests and agriculture in the mountains further emphasizing the need to have at least the minimum forest cover as prescribed above.

The agrarian economy of the hill region is heavily dependent on forest for energy supply, fodder, non-timber products and livestock rearing. The local people derive several livelihood benefits from forest ranging from Rs.2500 to 4000 per annum per family (Samra, J.S., 1999). There has been a gradual decline in the dense forest area in most of the states during the last decades. Forests support livelihood

by providing a large number of non-timber forest products (NTFP) and minor forest products (MFP).

Deforestation increases loss of nutrients like carbon, nitrogen, phosphorous and sulphur by 'leakage' from the eco-system leading to reduction in soil fertility, carbon fixation and organic matter accumulation. Under these conditions, only a few non-demanding but aggressive species invade open areas and establish themselves.Opening of canopy followed by increased insolation of the soil surface, slowed rate of organic matter decomposition and increased dryness of the soil has resulted in failure of natural regeneration in many originally forested areas. Such areas undergo more damage due to annual lopping patterns, removal of woody biomass for fuel wood and trampling by free grazing animals that effectively destroys any natural regeneration (Samra, J.S. and Raizada, A, 2001). Due to these uncontrolled factors, forest cover on a majority of Himalayan slopes, has retrogressed back to early successional stages, light demanding species and even aged species dominate with all aged populations becoming rare to observe. The resulting forest fragmentation is associated with plant and animal extinction, damage to the ecosystem and loss of biodiversity. This is due to firstly a reduction in the net area of natural habitat available and secondly creation of forest patches that are at a distance from each other that prevents movement of plant propagules and animals through forest corridors.

TABLE 5.3.3

Extent of Grazing and its Effect on Regeneration of Forest Species in the Himalaya*

States	*Forest areas affected by grazing (%)*			
North Eastern India	High	Medium	Light	Total
Arunachal Pradesh	3.0	17.9	31.9	52.8
Assam	6.7	13.7	29.1	49.5
Manipur	5.0	11.0	30.0	46.0
Meghalaya	4.1	17.8	42.2	64.1
Sikkim	4.8	20.1	29.6	54.5
Tripura	13.5	30.0	37.0	80.5
Mean	6.2	18.4	33.3	57.0

(Contd.)

(Table 5.3.3 Contd.)

States	*Forest areas affected by grazing (%)*			
Western Himalayas				
Himachal Pradesh	31.6	27.4	25.7	84.7
Jammu & Kashmir	17.4	53.2	25.4	96.0
Uttaranchal	13.0	35.4	33.3	81.7
Mean	20.7	38.7	28.1	87.4
All India	18.3	31.0	28.2	77.6

*Source : F.S.I.(1995). The State of Forest Report, 1995, FSI, GOI, Dehradun.

Invasion of *Lantana camara* upto 1500m and *Arundinaria falcata* at 1800-2800 m- a dwarf bamboo commonly called 'ringal' has led to complete absence of species regeneration in sal and oak forests respectively. *Chromalaema odoratum* another exotic weed occupies *mesic sites* in oak forests and forms dense thickets, preventing their natural regeneration. The dominance of weeds in forest areas, results in a reduction of biomass from several hundred tons ha^{-1} to about 30-45 tons ha^{-1} and increased portion of foliage. Shrubs found in oak forests fail to withstand strong sunlight due to canopy openings created by annual lopping and may vanish from these regions. All oaks are quite resilient and being good coppices may regenerate rapidly if no disturbance occurs.

Continued loss of forests and growing realisation about them as an important life support system led to bringing the subject in the concurrent list in 1976. It has been possible to reduce the rate of deforestation by enforcing Forest (Conversation) Act, 1980 and well-executed strategy for compensation afforestation. The rate of diversion of forest lands for other uses has gone down from 150,000 ha per year between 1950 and 1980 to 15,500 ha per year. (Tiwari,D.N. and Pandey, V.N. 2000). Qualitative loss of forest is, however, still continuing due to excessive collection of wood and NWFPs and damages by forest fires, grazing, pests and diseases. The National Forest Policy (NFP) of the country has been revised in 1988, with the principal aim of conservation of forests, biodiversity and environmental stability and also to ensure livelihood and security of forest dwellers and other rural people living in the vicinity of forests. The policy stipulates a national goal of having one-third of the country's land area under forest or tree cover from existing 19.27 per cent through massive afforestation and social forestry programme especially on all denuded and degraded and unproductive lands. The

policy envisages increasing the productivity of forests to meet essential national needs. It recommends efficient utilization of forest and maximizing substitution of wood. The policy states that the industrial wood requirement is to be met from farm forestry. It suggests the creation of people's movement with the involvement of women for achieving these objectives and to minimize pressure on existing forests (Anon, 1988).

The NFP stresses the need for involving people in the management of forests. The concept has been practiced as Joint Forest Management (JFM). The objectives of JFM are to regenerate and develop degraded forests for environmental needs and to provide fuelwood, fodder, NWFPs and timber to local people besides sharing forest revenue. The strategy of JFM has given a great impetus to the goal of sustainable forest management. The National Forestry Action Programme (NFAP-1999) has been formulated for the sustainable development of forests in conformity with the provisions of the NFP to address major issues of the forestry sector.

Improved management practices of forestry and agroforestry would go a long way in integrating forest with agriculture. The vital role of forests in protecting fragile ecosystems, freshwater resources and sequestration of carbon is well recognized. Trees, shrubs and other vegetation help control temperature extremes by moderating the desiccating effects of solar radiation and also increase relative humidity. Forests build up litters, which is of great importance for the water regime and regulated flow of water in rivers. By considerably decreasing the maxima of surface run off, forests reduce intensity of floods, the rate of soil erosion and deposition of silt in river beds and reservoirs and save agricultural lands from natural disasters.

Agroforestry is another land management system that optimizes land productivity by harnessing positive interactions between trees-crop-livestock system on land area. It is a holistic concept in which various organisms share a habitat. Conservation of natural resources and optimization of productivity could be considered as vital to its functioning. While at the small land holdings, agroforestry may provide livelihood security, at larger land holdings, it may be a profitable commercial proposition. The objectives of agroforestry are to take advantage of complimentary relationship between trees, crop and livestock in such a way that productivity, stability and sustainability of the system is enhanced and total gains from the

system exceed the combined gains from them individually. Agroforestry is being viewed as a restoration agent, rehabilitation process, bio-remediation mechanism and foster mother to high input agriculture on fragile lands. Its virtues are restoration of the system based on efficient nutrient cycle, nitrogen fixation in the soil, a good carbon sink and an agent for moderating microclimate and the environment.Agroforestry in hill regions requires special emphasis on the cultivation of indigenous trees species which have multiple economic and traditional importance (Singh G., et al, 2000.). In Western Himalayan zone, agroforestry are common to all. In high temperate zone, it is *Robina pseudoacacia* which is considered promising. Fruit trees get prominence in the farming systems in some areas. In the central part, at lower altitudes, agri-horti-system was found prevalent. Mango, litchi and citrus were the preferred trees. Forests were used for grazing animals. Fuel wood deficits are common and about 25% farmers purchase it. Research results show that a distance of 6-8 m from teak (*Tectona* it. *grandis*) and camphor (*cinnamomum/camphora*) did not depress the yield of rapeseed. At Solan, the growth of poplar was least affected when planted at 5 × 5 m and inter-spaces sown with wheat. The reduction of wheat was only 0.3t/ha compared with the control. Various agroforestry systems like agri-horticulture, horti-pasture and silvi-pasture are recognized as alternative land use for farmers in the hilly tract.

In Eastern Himalayas, large cardamom in association with *Alnus nepatensis (Utis)* and *Schima wallichi (chillowani)* and citrus in association with maize/ginger, soyabean/ginger is commonly practiced. Similarly potato and other vegetables often in combinations with pineapple which is grown in the slopes in association with pine (*Pinus kysia*) is very effectively utilized by growing ginger, turmeric etc.

5.4 FOOD CROPS

Food crop includes crop-species used in agriculture and their yields; usually refers to plants including cereals (crops of maize, rice, wheat, barley etc.), pulses, vegetables, oil seeds, fodder crops, codiments and spices

Mixed cropping is very popular in the Himalayan region. Cereals and millets are generally sown mixed with legumes (Arora, R.K. 1993) for example, finger millets (ragi) is grown mixed with black soyabean and wheat with lentil, or sometimes with mustard. The major crop

TABLE 5.4.1

Altitudinal Limit of Different Crops in the Himalayan Region*

S.No	*Crops*	*Altitude (m)*	*S.No*	*Crops*	*Altitude (m)*
I	*Cereals and*	*Millets*			
	Wheat, naked barley	4000		Ginger	1500-1800
	Hooded barley	3000			
	Buckwheat	3300	*IV*	*Fruits*	
	Amaranthus	3000		Pyrus, Prunus etc., Pome, Stone, Soft fruits, nuts (Walnut, chilgoza pine)	3000-3300
	Chenopods	2400		Citrus, Pomegranate	1800
	Proso millet	2400			
	Italian millet	2100	*V*	*Oilseeds*	
	Finger millet	2100		Brassica / Mustard	2100
	Barnyard millet	1800-2100		Linseed	2100
	Rice, maize	1800-2100			
	Sorghum	1500			
II	*Legumes*		*VI*	*Fodder types*	
	Scarlet bean	2100-2400		Medicago spp,	3000
	Fababean	2100-2400		Melilotus spp,	3000
	Field peas	2100-2400		Trifolcum spp,	3000
	Lentil	2100-2400		Lolium, Dactylis	3000
	French bean, Garden peas Soya-bean, rice-bean Black-gram, Horse gram	2100 1800	*VII*	*Tuber crops*	
				Yams, Taros, Moghania, artichoke	1800
			VIII	*Others*	
				Caraway	2400-2700
				Chikory, beet root, Kuth, hemp, Saffron, hops,	2400
III	Vegetables				
	Potato	3000			
	Cucurbita spp,	3000		Tea, tobacco	1800-2100
				Digitaria millet	1500-1800
	Chou-chour	2400			
	Cyclanthera	2100		Tree cotton, mesta, Sugar cane, bamboos	1500
	Hill radish				
	Leafy and Other Brassicae, Alliums	2100			
	Cucumber, garden peas, French bean	2100-2400			
	Chillies	1800			

*Source: Arora, R.K., 1993

production associations under mixed farming are the wheat / rice /ragi, maize / rice / wheat, maize / millets / rice and rice / maize /millets. Variations in these occur in different elevation zones under rainfed and irrigated conditions. Barley / wheat / pulses zone in higher altitude breaks up into barley / wheat / pseudocereals (buckwheat, amaranthus)– pulses. A very interesting combination in the eastern Himalayan region/northeastern region is of tea/horticultural crops/rice.

Wide variability in the agro-horticultural wealth exists from the sub-tropical, temperate to the alpine region, as far as timber line extends. The altitudinal limit of different crops grown in the Himalayas is given in the Table 5.4.1. The range and extent of genetic diversity in these crops differs within and among the hill ranges in the western and in the eastern Himalayas.

A large number of crops belonging to cereals, pulses, oilseeds and others are cultivated in the region. Self-sufficiency in food grain production is the primary objective of the farmers. They produce all those crops which can be cultivated by them in the harsh environment to meet their food requirements. It is apparent from the fact that 77% of the gross cropped area is under foodgrain crops as against 67% in rest of the country (Table 5.4.2).

TABLE 5.4.2

Area under Different Categories of Crops in Indian Himalayas*

(thousand ha)

States	*Food crops*	*Spices and condi-ments*	*Fruits*	*Vege-tables*	*Non-food crops*	*Gross cropped area*
Norh Eastern Himalayas						
Arunachal Pradesh	177	4	18	16	24	239
Manipur	163	7	4	10	5	189
Meghalaya	130	26	21	34	27	238
Mizoram	80	4	11	6	10	111
Nagaland	187	1	6	6	17	217
Sikkim	77	28	5	7	13	130
Tripura	271	6	56	41	60	434
Total	1,085	76	121	120	156	1,558
	(69.7)	(4.5)	(7.8)	(7.8)	(10.0)	(100)

(Contd.)

(Table 5.4.2 contd.)

States	*Food crops*	*Spices and condi-ments*	*Fruits*	*Vege-tables*	*Non-food crops*	*Gross cropped area*
Western Himalayas	848	3	195	28	4	1,078
Himachal Pradesh						
Jammu & Kashmir	880	2	128	15	111	1,136
Uttranchal	916	3	95	42	12	1,168
Total	2,644	8	418	85	127	3,282
	(80,6)	(0.2)	(12.7)	(2.6)	(3.9)	(100)
Total	3,729	84	539	205	283	4,840
Himalayas	(77.0)	(1.7)	(11.1)	(4.2)	(5.9)	(100)
Non	22,220	2,593	2,474	4,290	51,616	1,83,213
Himalayan Region	(66.7)	(1.4)	(1.4)	(2.3)	(28.2)	(100)
All India	1,25,449	2,677	3,013	4,495	51,899	1,88,053
	(67.0)	(1.4)	(1.6)	(2.4)	(27.6)	(100)

Figures in brackets are percent of gross cropped area *Source GOI (1998), ICAR (1998)

Research efforts are to be strengthened and intensified to generate enough basic data on population structure of threatened species, socio-ecological studies on species sharing the same ecosystem and monitoring of such studies in biosphere reserves in the Himalayan region.

5.5 HORTICULTURAL CROPS

Horticulture is the practical science or skill which deals with cultivation of fruits known as *pomology,* raising of vegetables known as *olericulture* and growing of ornamental trees meant for landscaping, beautification and fencing. Apart from the production of different kinds of fruits, vegetables, ornamental plants and flowers it also deals with their protection and preservation.

Horticulture is an economic activity of great importance to the Himalayan region, being the repository of invaluable germplasm for horticultural crops. As the tree crops protect soil erosion; the horticultural crops are most suited to hilly unirrigated and slopy lands. Further there are greater financial returns per unit land as compared to annual crops and the potential for income generation and employment is immense.

Due to climates ranging from sub-tropical to temperate, a wide range of fruits (citrus, banana, mango, apple, pineapple, walnut, plum, peach, cherries etc.), vegetables (potato, pea, capsicum, carrot, cabbage, cauliflower etc.), spices (garlic,ginger, chillies, cardamom, black pepper etc.) and flowers (orchids, gladiolus, marigold, chrysanthemum etc.) are grown in the region. Although these crops are well adapted, their cultivation is rather on a small scale at present. Total area under fruits and vegetables is 15.3 per cent of the gross cropped area ,which is much higher than in the non-Himalayan region (4.0 per cent) and all India (3.7 per cent) respectively (Samra, J.S., Dhyani, B.L. and Sharma, A.R.1999). Citrus, pineapple and banana are the major fruit crops of the NEH region, whereas apple, mango and citrus are important in the western region. The area and productivity of fruits is low, considering the range of niche available for their cultivation in the Himalayan region (Table 5.5.1). The

TABLE 5.5.1

Area and Productivity of Different Fruit Crops in Indian Himalayas*

State	*Area (thousand ha) under different fruit crops*						
	Mango	*Citrus*	*Banana*	*Apple*	*Others*	*Total*	*t/ha*
North-eastern Himalayas							
Arunachal Pradesh	1	3	1	-	13	18	2.24
Manipur	-	1	3	-	-	4	6.80
Meghalaya	-	7	5	-	9	21	8.72
Mizoram	1	6	3	-	1	11	4.86
Nagaland	-	1	1	1	3	6	1.73
Sikkim	-	4	1	-	-	5	2.03
Tripura	5	11	5	-	35	56	7.91
Total	7	33	19	1	61	121	8.23
	(5.8)	(27.3)	(15.7)	(0.8)	(50.4)	(100).	
	[0.54]	[2.2]	[1.0]	0.06]	[3.9]	[7.8]	
Western Himalayas							
Himachal Pradesh	3	2	-	72	118	195	2.94
Jammu & Kashmir	-	1	-	73	54	128	3.58
Uttranchal	8	1	-	54	32	95	2.08
Total	11	4	-	199	204	418	
	(2.6)	(1.0)		(47.6)	(48.8)	(100)	
	[0.37]	[0.1]		[6.7]	[6.7]	[12.7]	

(Contd.)

(Table 5.5.1 Contd.)

State	*Area (thousand ha) under different fruit crops*						
	Mango	*Citrus*	*Banana*	*Apple*	*Others*	*Total*	*t/ha*
Total Himalayas	18	37	19	200	265	539	438
	(3.3)	(6.9)	(3.5)	(37.2)	(49.3)	(100)	
	[0.4]	[0.8]	[0.4]	[4.1]	[5.5]	[11.1]	
Non-Himalayan Region	984	234	445	—	811	2474	13.28
	(39.8)	(94)	(18.0)		(32.8)	(100)	
	[0.5]	[0.2]	[0.2]		[0.4]	[1.4]	
All India	1,002	271	464	200	1,076	3,013	11.86
	(33.3)	(9.0)	(15.4)	(6.6)	(35.7)	(100)	
	[0.5]	[0.1]	[0.3]	[0.1]	[0.6]	[1.6]	

Figures in ( ) are per cent of total area under fruit crops and in [ ] are per cent of gross cropped area.

* Source: GOI (1997), ICAR, 1998.

western Himalayas have a sizable area under horticultural crops (12.7% of gross cultivated area), while the corresponding figure for the NEH region is 7.8 per cent only. The annual fruit production is about 30 lakh tonnes with an average productivity of 4.4 t/ha. The average productivity of fruits is about three times higher in the NEH region (8.2 t/ha) as compared to that in the western Himalayan region (2.9 t/ha). There exists a wide disparity in the production and productivity of fruit crops between the different states, indicating a vast potential for development of this sector. The apple productivity is much higher in Jammu and Kashmir (9-10 t/ha) as compared to H.P. (3-4 t/ha) and Uttaranchal hills (2-3 t/ha). There are many wild fruits such as apricot, pomegranate (anardana), mulberry, seabuckthorn, ficus etc. which are rich sources of vitamins, minerals and fatty acids.

Major constraints impeding horticultural development (Kaul, G.L., 1996) in the Himalayan region are :

- Low productivity of crops;
- Low use and availability of good quality inputs like seed/ planting materials, fertilizer, water, labour etc.;
- Acute absence of technological interventions;
- Weak research and extension support;
- Depletion of natural resources due to deforestation and urbanization;

- Remoteness of areas and inaccessibility of major markets;
- Absence of basic infrastructure; and
- Inadequate institutional support.

In spite of above problems, the Himalayan horticulture offers immense possibilities. The challenges are to be converted into opportunities for the welfare of local inhabitants and the sustainable development of the mountain region

The overall vegetable productivity in the Himalayan region is 40 per cent lower than all India average (Samra, J.S. et. al., 1999). Low productivity in most of the vegetable crops grown in the entire region is directly connected to the use of generally inferior varieties coupled with low input farming and heavy incidence of pests and diseases (Kaul, G.L., 1996). Several improved and high yielding varieties and F_1 hybrids recommended for the Himalayan region are listed in Table 5.5.2.

The Central Potato Research Institute (CPRI), Shimla has been in the forefront in developing several varieties of potato, suitable for different agro-climatic situations including north-western and eastern Himalayan region. These include high yielding and early maturing varieties like, Kufri Chandramukhi, varieties resistant to late blight (Kufri Jyoti, K.Naveen) for the entire region, resistant to Wart disease for Darjeeling area (Kufri Sherpa). For Meghalaya and adjoining area, Kufri Khasi-Garo has been released with resistance to late blight. Added to this, technology for production of healthy and disease free seed tubers developed and promoted by CPRI has ensured rapid multiplication of new varieties. The institute produces breeders' seed of these varieties every year for further multiplication by the state agencies.

Among spice crops, ginger occupies the major area with large diversity observed in varieties being used. However, most of the areain North-East region grows varieties with huge fibre content, thus not fit for dehydration. Improved varieties viz. Rio de-Janerio, Nadia, Burdwan, Maran etc. have recorded 18 to 23 tonnes of yield per hectare. Nadia has given the highest (22.2%) dry ginger recovery. In turmeric 'Suvarna' with high potential of 43 tonnes/ha and curcumin content of 8.7% holds good promise. In Jaintia hill district of Meghalaya, local selection 'Laccandan' is superior in quality and high in curcumin content, but has very narrow locational adoption. In chillies, apart from improved varieties of NP 46, Jawalla, Pant C-1

TABLE 5.5.2

Vegetable Varieties Recommended for Himalayan Region*

Crops	*Variety recommended*	*Remarks*
Brinjal	Pusa Purple Cluster KT4	Resistant to bacterial wilt and high yielding
Cauliflower	Pusa Subhra	Highly resistant to black rot
	Pusa Snowball K-1	Resistant to black rot, late maturing
	Pusa Himjyoti	Only variety producing curd from April to July in hills
Carrot	Pusa Yamdgni	Earlier than Nantes, high yielding and rich in carotene
French bean	VL-Boni-1	Dwarf, stringless suitable for multiple cropping on the hills.
	Arka Komal	Bushy, high yielding and good keeping quality
Peas	PM-2	Early, escapes powdery mildew
	VL-3	Resistant to powdery mildew and wilt
Tomato	Lincon	Good for canning, transport and shelf life
	Set-120	Nematode resistant
	Pant Bahar	Early, resistant to Verticillium and Fusarium wilt
	Pant T-3	Suitable for processing
	Arka Vikas	Tolerant to moisture stress
	Arka Saurabh	Resistant to fruit cracking; good transport quality and shelf life
Capsicum	California Wonder KT1 (F_1 Hybrid)	Late manuring Tolerant to bacterial leaf spot and anthracnose
Chillies	K2	Tolerant to thrips
Onion	Brown Spanish	High yielding and long shelf life
Potato	TPS-1/13 (F_1 hybrid)	Only 100 gms seed is required for 1 ha
	HPS-7/67 (F^1 hybrid)	Resistant to diseases and high yielding
Garlic	Agrifound Parvati	High yielding with large cloves suitable for export

* Source: Kaul, G.L. (1996)

and Pant C-2 (resistant to leaf curl) and K2, paprika has shown bright promise in HP; IARI Regional station, Katrain has developed an improved variety of paprika, which is high yielding and is also high in colouring characteristic usually attained under mild climate of hills.

5.6 MEDICINAL AND AROMATIC PLANTS

Himalayan herbs for medicinal purposes were documented in the Vedas (4500 to 600 B.C.), representing the oldest repository of human knowledge, comprising 67 plants species. Ayurveda provided further details for therapeutic use of as many as 290 herbal drugs (Manandhar, N.P., 1980). According to WWF (World Wildlife Fund for Nature), 2500 plant species are used as traditional healers and 100 species of plants are serving as regular sources of medicine (Shah, N.C., 1990). India occupies the topmost position in the use of herbal drugs utilizing nearly 540 plant species in different formulations. Presently, about 1000 single drugs and 8000 compound formulations of Ayurveda are in vogue (Joshi, G.C. et al, 1993).

Several medicinal and aromatic plants grow wild in the temperate habitats including the cold deserts. More diversity in medicinal plant species occurs in the Western Himalaya, generally between 1800 to 4000 m. Among the cultivated types saffron is grown in the Pampore region of Jammu and Kashmir but the genetic diversity prevalent is narrow (Arora, R.K., 1993).

About 1748 species (Angiosperms, Gymnosperms and Pteridophytes) of medicinal plants have been reported from the Indian Himalayan Region (IHR), of these 68.54% species are non-native and represent various bio-geographic regions such as Africa, Australia, Oriental India, Tropical Asia, Europe, America, China, Malaysia, Java, Islands of Indonesia, Japan, etc. About 25.80% species are native to Himalayan region and 5.66% species native to Himalayan region and neighbouring biogeographic domains. Of the native species, 62 species are endemic to IHR whereas 208 species are near endemic. Considering the distribution and use patterns of the species in different biogeographic provinces of the IHR, the maximum diversity of medicinal plants exists in Central Himalaya (i.e. Sikkim and Darjeeling Hills), followed by West Himalaya (i.e. Kumaon and Garhwal) and East Himalaya (Arunachal Pradesh and N.E. States), respectively (Samant S.S. et al. 1998).

The increased demand of medicinal plants in drug and

pharmaceutical industries based on different systems of medicines in India, have caused the over-exploitation of many species. Similarly, increasing biotic and anthropogenic pressures have caused degradation of natural habitats and decrease in the local population size of many commercially important medicinal plants of the Himalaya. This is the main cause that 17 species have been listed in the Red Data Book of Indian Plants (Nayar & Sastry 1987, 1988, 1990) and 62 species have been categorized as Critically Rare, Endangered, Vulnerable, Low Risk Near Threatened and Low Risk Least Concern at regional and global levels using current International Union for Conservation of Nature and Natural Resources (IUCN) criteria (Samant,S.S et al. 1998).

Keeping in view the importance of this group at local, regional, national and international levels, G.B.Pant Institute of Himalayan Environment and Development, Kosi – Katarmal has compiled and published a book on "Medicinal Plants of Indian Himalaya: Diversity Distribution Potential Values". The book deals with the species diversity, distribution and utilization patterns in different altitudinal zones and biogeographic provinces, similarity in the species distribution and utilization patterns within the biogeographic provinces, nativity, endemism, threatened medicinal plants, potential medicinal plants (wild edibles, multipurpose utility, fatty and essential oils, commerce/trade) and medicinal plants as wild relatives of crop plants and, also provides information on medicinal plants under cultivation, list of medicinal plants and herb suppliers, Institutions/ gardens where medicinal plants are being cultivated, farmers cultivating medicinal plants, species with known propagation protocols (tissue culture), phytochemistry, pharmacology, pharmacognosy and in the pharmacy of electropathy (Samant, S.S et al., 1998). Further to discuss the current issues on medicinal plants a three day Workshop on "Himalayan Medicinal Plants: Potential and Prospects" was organized during 5th-7th November, 1998. Experts and planners/policy makers from various Government and Non-Government Organizations participated in the Workshop and delivered Inaugural address, Keynote address and lectures on the following themes:

- Status of Himalayan Medicinal Plants: Inventory, Folk and Ethnobotany
- Population Studies: Threatened Medicinal Plants

- Propagation Methods: Current Status
- Cultivation and Domestication
- Utilization, Extraction, Phytochemical Investigations and Conservation

The deliberations during the Workshop as also the available data base precipitated a feeling that population study of identified threatened medicinal plants need to be initiated to understand the ecological processes involved in the natural habitats/systems. It was also felt that agrotechnologies and propagation protocols need to be developed for the sustainable utilization, conservation and management of threatened medicinal plants. (Samant, S.S. et al 2001).

The plant diversity in the Indian Himalayas constitutes an indispensable source of raw material for drugs, pharmaceuticals, perfumery, cosmetics, aroma chemicals, dyes, food colours, gum, resin and a myriad of related industries. Nonetheless, the establishment of pharmaceutical sector is handicapped due to several constraints (Samra, J.S. et al., 1999). The industrial units in organized sector demand regulated supply of quality raw materials. Presently, these plant materials are collected from the natural population indiscriminately and cannot provide sustained supplies for a longer period. Extraction from the forest area is unregulated and excessive exploitation has endangered many species. Extinction of plant species in the cold desert areas of Leh, Ladakh and Lahul and Spiti is alarming. Cultivation of medicinal plants in private or organized sector for commercial purpose is not common. Infrastructure for standardizing planting practices is inadequate. The efforts made by the Central Institute for Medicinal and Aromatic Plants (CIMAP), Lucknow are confined mostly to the foothills. The research center at Lal Kuan is not equipped to attend to the vast Himalayan region. The cultivation of medicinal and aromatic plants in hills is technically feasible and economically viable. However, low seed set, poor seed viability, high dormancy and poor germination are responsible for their low production. Processing of medicinal and aromatic plants requires large capital and skilled manpower which is not available. The State governments do not encourage long lease of forestlands for establishing plantation by corporate sector.

There is a need to draw a detailed plan for preservation, maintenance and promotion of various medicinal plants and herbs ensuring participation of local people for growing them in cultivator's fields and various forest habitats.

5.7 LIVESTOCKS

Livestock has become an integral part of Himalayan production systems. Animal products like milk, butter, meat, wool, skin, bones, dung etc. have been used by the community since the dawn of civilization. Transport by animals in the difficult terrain of the hills is another important service.

The cattle constitute about 48 per cent of total livestock population and about 95 per cent of local, tiny and low yielding animals (Samra, J.S. et al 1999). The milk yield varies from 1 to 1.5 litre/day and lactation period from 190 to 230 days. The people keep large herds not only for milk but for manure as well, which is the major source of nutrient transfer from forests and rangelands to the agricultural fields. The local cows are better acclimatized and can move easily in the difficult hilly terrain for grazing. Cross breeding with Holstein Freizen has high potential but it has to be reared by stall feeding. The people are also rearing buffaloes for milk production in the valleys and low hills. The milk yield of buffaloes is 4 times higher than cows but the former are not ideally suited for grazing. The productivity of sheep, goats, pigs and poultry is also low. Comparative economics of various animals reared in the region indicates superiority of local cows due to grazing advantage.

The people in the Kashmir valley are predominantly meat eaters. They prefer meat of sheep and goats, and require dual-purpose breeds of these animals for wool as well as mutton production. Pig is priced animal of the NEH region. Yak rearing is mainly confined to the high altitude zone of Ladakh region in J&K and the NEH region. It is a multipurpose animal with low milk yield but with more fat content. Similarly, mithun, a tamed wild cow or buffalo, is mainly confined to Arunachal Pradesh, Manipur, Nagaland and partly to Mizoram. The milk yield is low but meat is tender and juicy. Besides, mithun is well adapted to grazing in the hilly tract. Improvement of yak and mithun is called upon for higher milk production and other services. The NEH region is importing eggs and meat from other states in spite of the high potential of dual purpose backyard poultry.

Major constraints for enhanced productivity are health care, mass multiplication of desirable breeds, improved nutrition and control of animal density. It is estimated that the grazing pressure is three times more in H.P. and five times more in Uttaranchal than the carrying capacity of the pasture lands in these states. This needs control of

animal population density or alternalely to improve the management of pastures and grasslands, to save the land from desertification.

5.8 FISHERIES

Amongst 258 fish species identified from Indian uplands, 203 are reported from Himalayas while 91 from the Deccan plateau (NRCCWF, 2000). 105 fish species (both cold and warm water forms are recorded from different rivers and water courses of Arunachal Pradesh (Nath, P and Dey, S.C., 1985). A multitude of anthroprogenic factors have resulted in stress to aquatic biodiversity causing adverse impact on these fragile ecosystems and fish populations. The much affected fish species in the Himalayan region are mahaseers, snow-trout, Indian trout and exotic trout. Based on detailed evaluation regarding their abundance and availability nearly 33 important species have been categorized as depleted stocks comprising both commercial as well as sport species.

During early fifties, quite a good sized golden mahaseer specimens have been recorded from different ecosystems in the central Himalayan waters viz. about 22 kg specimen from Bhimtal lake, specimens in the weight range of 15-17 kg from river Yamuna and 30-35 kg from river Saryu. But subsequently, the size of the fish has shown steady decline. Presently from Himalayan upland waters, the usual weight range of fish is between 100-1500 g with occasional weight of more than 3 kg. There has been a drastic depletion in overall catch structure of golden mahaseer over the years as depicted in Table 5.8.1.

TABLE 5.8.1

Depletion of Golden Mahaseer over the Years*

Water body	*Period*	*Catch (in quintal)*
Bhimtal lake (Uttaranchal)	1983-84	0.530
	1990-91	0.245
Saltal lake (Uttaranchal)	1983-84	0.050
	1990-91	0.020
Govindsagar (H.P.)	1976-77	468.70
	1989-90	31.40
Pong reservoir (H.P.)	1982-83	101.49
	1990-91	59.50

*Source: NRCCWF, 2000

The position of snow-trout fishery is also not very encouraging especially in lentic (living in still water) system which were previously rich in its fishery. The situation has reached an alarming stage in Kashmir and Uttaranchal's lakes where some of the species are very much localized. During the period indicated below, snow-trout catches have drastically declined as reflected from Table 5.8.2.

TABLE 5.8.2

Depletion of Snow-Trouts over the Years*

Water body	*Period*	*Snow-trout catch*	*(%)*
Dal lake	(J&K)	1968-87	20.3
Wulur lake	(J&K)	1980-83	32.4
Anchar lake	(J&K)	1977-79	19.5
Manasbal	(J&K)	1977-79	27.8
Naranbagh	(J&K)	1980-82	20.7
Bhimtal	(Uttaranchal)	1984-90	0.7
Naukachiyatal	(Uttaranchal)	1984-90	0.3

*Source : NRCCWF, 2000.

The general weight frequency of snow-trout normally ranges between 80-1000g. Rarely specimens of more than 2 kg are caught from lentic systems however, in lotic systems (living in flowing water) larger specimens have been reported. Though the status of snow trout catches in fluvial systems has not reached to such an alarming situation but their overall catches have definitely gone down by 10-20% over the years.

In the case of brown trout, a definite downward swing in number of specimen caught /rod, the prescribed bag-limit and average size of trout hooked has been recorded from various streams of Kashmir and Himachal Pradesh (Table 5.8.3).

Indian trout *(Raimus bola)* extending in its distribution from western to north-eastern Himalaya is almost endangered variety. Even in seventies, about 2 kg specimen were recorded from the Bhoreilli (Assam) but now very rarely, specimen of even 500 g are caught, while from the north Indian waters, the species has almost vanished.

For planning and designing of upland fisheries management and conservation strategies, the basic pre-requisite involves regular hydro-biological monitoring of water resources. Since the coldwater fish

TABLE 5.8.3

Downward Swing of Brown-Trout in Streams*

Water Body	*(Streams)*	*Period*	*Average Weight(g)*
Bringi	(J&K)	1965	1400
		1974	810
Erin	(J&K)	1965	800
		1974	480
Lidder	(J&K)	1969	275
		1972	175
Sind	(J&K)	1969	385
		1972	210
Beas	(H.P.)	1965	260
		1987	87

*Source: NRCCWF, 2000

species are sensitive to both temperature and water quality, its population is affected in various ecosystems.

The conservation strategy should involve the following regulatory measures :

- Strict enforcement of fishery regulations
- Prevent destructive and illegal fishing
- Protect breeding grounds
- Catchment improvement for water quality
- Conservation of natural fish seed and mass scale seed production
- Phased and regular ranching programme of endangered species.

Management strategies for freshwater fisheries are based entirely on actual population parameters and catch per unit effort (CPUE) data. Historically, methods such as restocking, predator removal, habitat restoration, the implementation of closed seasons and fish size / catch limits have been used to augment freshwater fisheries. Current theory suggests that freshwaters should be managed on a whole-catchment scale. The integrated approach acknowledges the role that other users of the aquatic and terrestrial environment may have on the well-being of both riverine and lacustrine fish stocks.

5.9 MICRO-ORGANISMS

Micro-organisms developed long before the planet earth and became aerobic before carbohydrates became dominating primary organic

material. Microbes are tiny living creatures and their peculiar features of microbes are:

- Ability to live under anaerobic conditions
- Can utilize inorganic compounds for their growth
- Ability to fix atmospheric nitrogen and solubilize phosphorus
- Can utilize C compounds like methane
- Small size possessing structural and physiological flexibility
- Have short generation time.

Micro-organisms play a crucial role in various processes related to soil quality and plant production. They offer an excellent opportunity to sustain agriculture by harnessing microbial technologies (Wani, S.P., 2000). Soil micro-organisms are primary decomposers of organic matter and play a critical role in C and N cycles in the nature and act as nutrient-flow regulators. Soil microbial biomass is defined as the living part of the soil organic matter, excluding plant roots and soil animals larger than 5×10^3 μm^3. Microbial biomass C and N can effectively be manipulated in soil through appropriate combination of crops and soil management practices. Such manipulations help in sequestering more C in soil, increase nutrient supplying capacity of soils and can also increase efficiency of the applied nutrients.

Biological nitrogen fixation (BNF) plays an important role in sustaining systems productivity in the nature. Symbiotic partnership between rhizobia / bradyrhizobia and legumes contribute significantly to N-cycle in the agricultural systems. Biological nitrogen fixation in the tropics plays an important role in sustaining systems for agricultural production. However, the potential of BNF is not yet fully harnessed due to technical problems involved in successful establishment of the symbiotic partnership at desired level under field conditions. Diversity of the cropping systems need to be achieved through inclusion of high value legumes in the system. The benefits of this partnership can be harnessed to the maximum through development of suitable technologies. Still the question of establishing efficient and compatible strains of rhizobia as inocula for many field situations is eluding. Without a solution to the competition problem, the introduction of genetically improved symbionts will have little practical impact. Most symbiotic processes are under direct control

of the host plant. Yet in Nitrogen fixation research, little emphasis is placed on the plant compared to the microbial component. Some research on host genetics of legumes has indicated the positive gains in terms of increased nitrogen fixing lines (Datta, M., 1985) and plants mutants selections that are tolerant to the symbiotic inhibitor effects of high soil nitrate levels. Management practices also can be manipulated for harnessing maximum benefits from rhizobia-legume symbiosis. There is need to approach such problems in a holistic system.

In recent years, biofertilizers have emerged as an important component of integrated nutrient supply system (INSS). Biofertilizers, both N-fixers and P-solubilizers are not only beneficial but also minimize the cost of production (Dwivedi, G.K., 2000).

Agricultural biotechnology offers a new approach for development of alternative, efficient and ecologically safer control of plant diseases (Chet, I & Chernin, L, 2000). About 20 different genera of bacteria and fungi have been shown to be potential bio-control agents for numerous plant diseases.

An immense diversity exists among micro-organisms and even within a group of micro-organisms. Microbial diversity encompasses a spectrum of microscopic organisms including bacteria, fungi, actinomycetes, algae and protozoa. An estimated 50 per cent of all living population on earth is microbial. Culture collections all over the world including India have been playing a major role in preservation of micro-organisms. At present there are about 500 culture collections in 58 countries which hold about 810,500 cultures (Tilak, K.V.B.R., 2000).

TABLE 5.9.1

Cultures held in Culture Collection*

1.	Bacteria including archaebacteria	3,43,253
2.	Filamentous Fungi	3,72,304
3.	Viruses	14,370
4.	Other kinds of micro-organisms	80,000

* Source: World Federation for Culture Collections 1997 News Letter, 22 July issue.

5.10 BIODIVERSITY

Earth's survival depends on maintaining the biological diversity. The biological diversity is very large. Biodiversity supplies us with the basic necessities – feeds us, cures our ills, provides new raw materials for our industries, beautifies, inspires and enriches our physical and spiritual life.

Biodiversity (the multiplicity of life forms) is "the property of living systems of being distinct, that is different, unlike" (Solbrig, O.T. 1994). Biodiversity, categorized at different levels owes its origin to a variety of macromolecules, most notably DNA and proteins. In essence, Himalayan biodiversity is the manifestation of variety and variability in genes, populations and ecosystems (see the following for connected definitions).

Biological diversity *refers to the variety and variability among living organisms and ecological complexes in which they occur. It encompasses different ecosystems, species, genes and their relative abundance. Thus, biological diversity is considered at three different levels.* ***Ecosystem diversity*** *relates to the variety of habitats, biotic communities and ecological processes in the biosphere. For example, a landscape interspersed with croplands, grasslands and woodlands exhibit more diversity than a landscape of fragmented woodlands.* ***Species diversity*** *refers to the number of species existing within the discrete geographical boundaries. A pasture land with 100 species of annual and perennial grasses and shrubs have more diversity than similar but disturbed pasture lands.* ***Genetic diversity*** *refers to the total genetic information contained in the genes of individual plants, animals and microorganisms. Thus, an environment that includes both the domestic varieties of a crop and its wild ancestors have more diversity compared to a similar but wild ancestors free environment.*

*Source: Mc Neely,J.A., et.al., 1990

A general summary on biodiversity status is given below (Cox, C.B. and Moore, P.D.,2000) :

(i) Biodiversity means the full range of life on earth, including all the different species found, together with the genetic variation between populations and individuals and the variety of ecosystems, communities and habitats present on our planet.

(ii) We are losing species at an unknown, but accelerating rate.

We need to know more about the variety of life on earth before we can even appreciate how fast we are losing it.

(iii) There are probably between 12 and 30 million species on earth, but only 1.8 million have been described.

(iv) The tropics are generally richer in species than the high latitudes, possibly as a result of high productivity and food availability, high biomass and hence complex structure, past patterns of evolution, survival of fragments of habitats through the cold episodes of the last two million years and also the degree of small-scale disturbance resulting in a mosaic of successional processes.

(v) The term 'diversity' involves both species number (richness) and the pattern of allocation of numbers or biomass between the different species (even-ness). It generally increases during the course of succession.

TABLE 5.10.1

The Numbers of Described Species in Selected Groups on Organisms, together with the Likely Total Number on Earth, the Percentage of the Group that is Currently Known*

Group	*Described species*	*Likely total*	*Percentage*
Insects	950,000	8000,000	12
Fungi	70,000	1000,000	7
Arachnids	75,000	750,000	1
Viruses	5,000	500,000	5
Nematodes	5,000	500,000	3
Bacteria	4,000	400,000	1
Vascular Plants	250,000	300,000	83
Protozoan	40,000	200,000	20
Algae	40,000	200,000	20
Melluses	70,000	200,000	35
Crustaceans	40,000	150,000	27
Vertebrates	45,000	50,000	90

*Source: Groombridge B(ed) Global Biodiversity : Status of the Earth's living Sources, London, Champan and Hall, 1992.

Himalayan region is world's richest ecosystems in terms of biodiversity. The region is characterized by diverse ethnic groups which have developed their own cultures based on available natural resources, giving rise to cultural diversity at par with the high level of biological diversity. The Himalayan biodiversity presents a truly Himalayan task in inventorization, conservation and sustainable use.

Due to a great variety of physiographic and phytoclimatic conditions, the Himalaya foster almost all types of vegetation, from humid tropical evergreen to moist mixed deciduous sal forests, marshes, swamps, mixed deciduous forests, subtropical pine forests, broad leaved temperate forests, moist temperate broad leaved deciduous forests, temperate conifer forests, sub-alpine and alpine vegetation, alpine meadows and alpine scrubs.

The present state of knowledge shows that the western Himalaya is comparatively better understood as compared to the Eastern Himalaya as a considerable portion of this region is botanically still *terra incognita* (Singh, D.K. and Hajra, P.K., 1998). The approximate plant diversity in the Himalayan region is given in Table 5.10.2.

About 40 per cent of the Himalayan flora is endemic. The Western Himalaya are richer in medicinal plant diversity as compared to their Eastern counterpart. The Himalaya is a precious treasure-house for a large number of plant species which are collectively known as *non-*

TABLE 5.10.2

Plant Diversity in the Himalayan Region (approximate)*
Total number of species

	Himalayan region	*India*	*World*
Angiosperms	8,000 (3200)	17,000 (5400)	2,50,000
Gymnosperms	44 (7)	54 (8)	600
Pteridophytes	600 (150)	1,022 (200)	12,000
Bryophytes			
(a) Liverworts	500 (115)	843 (146)	8,500
(b) Mosses	1,237 (450)	2,000 (820)	8,000
Lichens	1,159 (130)	1,948 (423)	20,000
Fungi	6,900 (1890)	13,000 (3000)	1,20,000

* Source: Singh, D.K. and Hajra, P.K., 1998. Figures in parentheses represent the number of taxa considered endemic to Indian Himalayan region.

timber forest products (NTFP) or the *minor forest products (MFP).* These plants are an important source of essential oils, spices, wild edible plant, gums, resins and oleoresins, fatty oils, tannins, natural organic colouring materials, katha and cutch, oxalic acid, fibres and flosses, beverages and narcotics, fodder and forage, saponins, fish poisons, insecticides and raticides, green manure etc. besides of course the medicinal plants and a number of multipurpose plants which play an important role in the socio-economic life of the people in the region.

The Himalayan region has rich diversity in forage plants. This includes about 13 genera and 100 species of legumes, and 22 genera and 160 species of grasses. Based on the data of Arora, R.K. and Nayar, E.R., 1984, there are around 399 species of wild relatives of crop plants belonging to 90 genera in the Western, Eastern and North Eastern Himalayas as shown Table 5.10.3

TABLE 5.10.3

Distribution of wild relatives of crop plants in the Himalayas*

Crop group	*Genera represented (Number)*	*Species represented (Number)*		
		Western Himalayas	*Eastern Himalayas*	*North Eastern Region*
Cereals & Millets	15	29	16	
Legumes	7	9	5	6
Vegetables	17	25	12	27
Fruits	25	37	32	51
Oilseeds	3	6	3	1
Fibres	6	4	4	5
Species & Codiments	8	10	9	13
Miscellaneous	9	5	10	13
Total species diversity	90	125	82	132

*Source : Arora, R.K. and Nayar, E.R., 1984

More specifically, the Himalayan region has been the source of several cereals, pulses, fruits, oil-yielding plants, spices, tuberous vegetables, and sugar yielding plants and their close wild relatives which number 125 in western Himalaya, 82 in the eastern Himalaya and 132 in the contiguous belt of north eastern region.

Below is the modified list of major and minor crops grown in the Himalayas and the foothills (Arora, R.K., 1993) :

A – Rabi crops

Cereals	:	Wheat, barley
Pulses	:	Gram, lentils, field peas
Vegetables	:	Cauliflowers, cabbages, turnip, radish, carrot, garden pea, fenugreek, tomato, potato, spinach, onion, garlic.
Oilseeds	:	Linseed, rapeseed, mustard, taramira
Fodder Crops	:	Oats, Lucerne, Persian cloves, Egyptian cloves
Condiments and Spices	:	Coriander, fennel, cumin, caraway, chicory

B – Kharif crops

Cereals, millets		Paddy, maize, sorghum, prosomillet, Foxtail millet, Finger millet, barnyard millet,
Pulses	:	Black gram, green gram, moth bean, horse gram, cowpea, ricebean, adzuxibean, pigeonpea
Vegetables	:	Squash, bottle gourd, round gourd, bitter melon, tuber gourd, smoth gourd, cucumber, long melon, musk melon, water melon, aubergine potato, sweat potato, French bean
Oilseeds	:	Seasame, groundnut, castor, soyabean, black soyabean
Sugar crops	:	Sugarcane, Suar beet
Fibre crops	:	Sorghum, cluster bean, guinea grass, napier grass
Condiments	:	Ginger, turmeric, chillies, field mint, Garlic, Perilla
Spices etc.	:	Tobacco

C. Tobacco is grown in between rabi, and toria/Brassicae, artichoke and asparagus in between Kharif

The agrobiodiversity which evolved through years of natural selection is of paramount importance for any crop improvement programme. The north-western Himalayan region represents a wide range of agroecological niches due to interplay of different climatic factors and is endowed with treasure house of agro-bio-diversity. The

richness of agro-biodiversity played a vital role in sustaining the hill farming system.

The significance of utilization of agro-biodiversity in genetic improvement of major hill crops were realized by Vivekananda Parvatiya Krishi Anusandhan Sansthan, (VPKAS), Almora long back and continued systematic efforts have been made in harnessing it. More than 5000 native exotic collections in major hill crops were evaluated and efforts were made to conserve them. Concerted attempts have been made by the team of agricultural scientists of this institute to utilize this wealth of agro-diversity for genetically improving the major hill crops. These efforts led to the development of 23 high yielding and eco-friendly varieties of 13 crops at this institute (Chauhan, V.S. et al 1998). Of these, 5 were released by Central Varietal Release Committee (CVRC) whereas remaining 18 were released by State Varietal Release Committee (SVRC). Efforts are underway to exploit the desirable attributes of native or exotic genetic resources through recombination breeding by judicious combinations of desirable genotypes to further enhance and sustain the productivity of major hill crops to meet the challenge of ever increasing demands of growing population of the region. Hill campus at Ranichauri of G.B.Pant University of Agriculture and Technology, Pantnagar has contributed in terms of improved varieties particularly in the underutilized evolving pseudo cereals, grain crops of Himalayan region. (Datta, M. et al, 2002).

Apart from the above, a host of other species have been introduced into the agricultural system, and these are actually being cultivated, some even on a large scale. These species range from agricultural crops to tea and rubber, to apricot, peaches, plums, cherries, almonds, apples, pears, grapes, pomegranates, quince, mulberries, kiwi fruit, myriaca, chestnuts, walnuts, hops, and others (Khoshoo, T.N. 1996).

Let us recall that the the life on our planet appeared about 3.5 billion years ago. It originated most likely in shallow warm seas. Adjusting to new settings of earth environment, living organisms have become increasingly complex with the passage of time. Life exists not only in the moist, warm niches on land but thrives in the driest of deserts and on cold mountain tops (Gadgil, M., 1997). Without exception every living thing must maintain a flux of energy-rich matter. The machinery of early organisms could not, in fact, tolerate free oxygen. The ability to use oxygen greatly quickened the pace of life on earth. When creatures tapped light energy, they evolved

pigments like chlorophyll. Concentrating the chlorophyll in specially structured bodies further enhanced the efficiency of the process of photosynthesis. And then as plants invaded land, a whole range of new structures had to be formed to resist rapid loss of water to fight gravity. So plants began to produce large quantities of tough yet flexible molecules of cellulose, so that cellulose is today the most abundant of molecules on earth. Desert plants have evolved a more complex form of photosynthesis that permits them to postpone having to take in CO_2 till night time. Fossil records show a nearly continuous increase in the number of plant species on the land. The mutual interaction amongst plants and animal pollinators and seed dispersers as well as the ever escalating "arm race" between plants and animals feeding on them have played an important role in promoting their diversification. Animals on land account for a bulk of species on earth today. This figure represents the total number of species of land animals of different sizes. A plot of number of species of all different kinds of terrestrial animals (on logarithmic scale) with their body length (on linear scale) shows that the diversity reaches a peak in the size range of 5 mm. to 1 cm and declines thereafter (Bonner, J.T., 1988).

Feeding on other plants and animals locks many animals into a contest with their victims. While the victims continually evolve new ways to foil predators, the predators evolve to overcome these defences. Antelopes become ever fleeter of foot, cheetahs evolve to run faster. While rhinos and elephants evolve a large size and thick hides, lions and tigers get to be large enough to tackle the young, if not full grown adults of these species. In the rain forest, lush green leafy matter is consumed by a myriad insects. Rainforest plants produce a whole range of toxic chemicals to counter this threat. In turn the insects evolve means of neutralizing these poisons. It is this chemical warfare that is responsible for the evolution of the many valuable drugs that human extract from the plants of the humid tropics.

But animal, plant and microbial species do not only subsist at the cost of each other. They often help each other. The early land plants relied on wind and water to carry pollen and disperse seeds. Plants evolved flowers to attract pollinators to reward them with a sugary nectar. Pollens will be wasted if deposited onto a flower of a different species. Therefore, flowers of distinctive sizes, shapes, colour pattern were developed by plants to ensure that a pollinator would move on to another flower of the same species. Plants have also developed fruits whose flesh rewards animals for dispersing their seeds. Thus,

the history of life has therefore been a process of continual increase in the variety of life.

The faunal diversity of the Himalayan region show extreme adaptability to the harsh environmental conditions under varied habitat conditions offered by forests, lakes, rivers, understones and invertebrates.

Some species like snow leopard may come upto nearly 5000 m while others like sheep, mountain goat, ibex, yak can move to about 5000 m; small mammalian species can also be recorded to 4500 m altitude but the Himalayan black bear wanders from 2000 m to 2300 m (Ghosh, A.K. 1996).

The distribution of mammalian diversity in the Himalaya shows that about 25% is of Palearctic origin, while Oriental elements constitute 65%, Ethopian and other elements compose rest of the 10%. The avian fauna has been studied by naturalists, professional ornithologists/ zoologists and detailed documents are available for different regions. Synthesis for the whole region is not available. The species distribution of reptilian, amphibian and fish fauna is tabulated in Table 5.10.4.

TABLE 5.10.4

Reptilian Fauna in the Himalaya* (Number of species)

Western Himalaya (314 m-3322 m)	*Central Himalaya (618 m-2005 m)*	*Eastern Himalaya (1871m-5000 m)*	*NE Himalaya (395 m-2500m)*
32	30	60	90
Total from the Himalaya – 149 species; Endemic – 29 species.			

* Source: Ghosh, A.K.,1996

TABLE 5.10.5

Amphibian Fauna in the Himalaya* (Number of Species)

Western Himalaya (314 m-3322 m)	*Central Himalaya (618 m-2005 m)*	*Eastern Himalaya (1871m-5000 m)*	*NE Himalaya (395 m-2500 m)*
17	16	26	54
Total from the Himalaya – 74 species; Endemic – 35 species; Typical to Himalaya – 25 species.			

Ghosh, A.K., 1996

TABLE 5.10.6

Fish Fauna in the Himalaya* (Number of Species)

Western Himalaya (314 m-3322 m)	*Central Himalaya (618 m-2005 m)*	*Eastern Himalaya (1871m-5000 m)*	*NE Himalaya (395 m-2500 m)*
80	130	44	159
Total from the Himalaya – 218 species; Endemic – 56 species; Typical to Himalaya – 35 species.			

*Source: Ghosh,A.K..1996

5.11 CONSERVATION MEASURES AND BIOSPHERE RESERVES IN INDIAN HIMALAYAS

The ongoing *in-situ* conservation measures for biological diversity include setting of Protected Area Network, Biosphere Reserves including protected areas, scientific and sustainable use of wetlands, sacred grooves etc. *Ex-situ* conservation measures include setting up of Botanical Gardens, Zoological Gardens, Gene-Banks. The National Environment Awareness Compaign Programme facilitates creating awareness for the conservation of biological diversity. (Ahuja, A.K., 1998).

At the initiative of UNESCO's Man and Biosphere (MAB) programme, the idea of "Biosphere Reserves came forth in 1974. The main objectives of Biosphere Reserves (Sharma, J.K., Easa, P.S. Mohanan, C.Sasidharan, N., Rai, R.K., 2002) are :-

(i) Conservation of biodiversity and their ecological foundations;
(ii) Bring representative ecosystems under conservation and sustainable use on long term basis;
(iii) Ensure participation of local inhabitants for effective management and devise means of improving alternate livelihood through sustainable use of natural resources;
(iv) Integrate scientific research with traditional knowledge of conservation and facilitate education and training as a part of overall management of Biosphere Reserves.

Each Biosphere Reserve has three basic functions:

(i) A conservation function : to contribute to the conservation of landscapes, ecosystems, species and genetic variation;

(ii) A development function: to foster economic and human development which is socially and ecologically sustainable;

(iii) A logistic function: to provide support for research, monitoring, education and information exchange related to local, national and global issues of conservation and development.

For management purposes, each Reserve is divided into three zones;

Core zone is a strictly protected area where human activities are not allowed. It provides opportunity for monitoring evolutionary changes and serves as a totally protected area for national regeneration of biodiversity.

Buffer zone is the area surrounding the core zone where low impact activities are allowed.These include environmentally sustainable use of natural resources and development, research, environmental education and regulated recreation.

Transition zone is the zone out side the buffer zone where intense human activities on sustainable use of resources by local communities is encouraged.

There are six operational (Nanda Devi, Khangchendzonga, Manas, Nokrek, Dibru- Saithowa, Dehang -Debang) and four proposed Biospheric Reserves (Cold Desert, Valley of Flowers, Kaziranga, Namdapha) in the Indian Himalayas

The salient features of the operational Biospheric Reserves are as follows:

TABLE 5.11.1

Salient Features of Operational Biosphere Reserves*

S. No.	*Biosphere Reserve -area, state and biogeographic province*	*Vegetation Types*	*Important Plant Species*	*Important Animal Species*
1.	**Nanda Devi** (5860.69 km^2) Uttaranchal, West Himalaya	Mixed temperate coniferous forests Mixed temperate deciduous forests, temperate pasture, Alder forests	*Primula sp. Orchis, Latifolia Rhododendram sp. Saussurea spp., Potentilla sp. Altingia excelsa, Shorea assamica*	Snow leopard Himalayan tahr musk deer

(Contd.)

(Table 5.11.1 Contd.)

S. No.	*Biosphere Reserve -area, state and biogeographic province*	*Vegetation Types*	*Important Plant Species*	*Important Animal Species*
2.	**Khangchendzonga** (2619.92 km²):Sikkim, Central Himalaya	Sub tropical broad leaved hill forests, Himalayan wet, temperate forests, coniferous forests Alpine forests	*Aconitum spp. Rhodo-dendron spp. Costus speciosus, Paphio-pedilom sp.* (Orchid)	Leopard cat, panther, snow leopard, musk deer, clouded leopard, Mixed red panda, Black eagle Himalayan beard vulluri.
3..	**Manas** (2837 km²): Assam North East Brahamputra Valley	Evergreen forests, Semi evergreen forests, cane and bamboo brakes, Mixed deciduous forests, grass lands	*Shorea assamica Attingia excelsa, Bambusa spp., Calamts spp. Vatica sp., Glochidion sp.*	One horned rhinoceros, elephant, golden langur (endomic), sloth bear Hoslock Gibson, donded salvator leopards
4.	**Nokrek** (820 km²) Meghalaya North East Hills	Evergreen forests, Semi-evergreen forests, Moist deciduous forests, Mangrove forests	*Cyathea albo-setacea (tree farn) Phalaae-nopsis Speciosa (Orchid) Diptero-carpus sp., Garcinia spp. Pandanus spp. Dendrocalamus*	Cra eating macagne, dugong, Nicobar tree strew, Megapode, Salt-water crocodile, sp reticulated python
5.	**Dibru-Saikhowa** (765 km²) Assam, North East Brahmaputra Valley	Deciduous forests. Riverine forests	*Salix tetras-perma, Ficus spp., Bischofia gavanica, Dal-bergia sp Steno-chaena palus spp.Macaranga sp. Pandanus sp. Rhododendron sp., Dendrobium sp., Cymbidium sp. Eria sp.*	Elephant, tiger, wild buffalo, feral horse, Hoolock gibbon, white winged wod duck
6.	**Dehang-Debang** (5111.5 km²) Arunachal Pradesh North East Himalaya	Evergreen forests, Subtropical ever-green forests, Grasslands	*Terminalia myrio-carpa Ailanlhus grandis, Ficus spp. Macaranga sp. Pandanus sp. Rho-dodendron sp., Den-drobiom sp., Cymbi-dium sp. Eria sp.*	Leopard, musk deer, serrow takin, goral, sclatter monal – East blood pheasant khalis pheasant

* *Source* : J.K.Sharma et., al., 2002

The above reserves have been notified since 1988 onwards. The range of activities in the buffer zone of existing Biosphere Reserves include :

- Ecodevelopment activities such as providing safe drinking water; alternate energy sources such as gobar gas and solar lamps; solar electric fencing to protect crops from wild animals; and distribution of implements for alternate livelihood options such as rope making , wool industry and leaf plate making.
- Protection activities such as provisions of walkie-talkies, fire arms, picket stations and watch towers for Forest Development Officers.
- Eradication of alien species like *Lantana* etc.
- Establishment of nursaries for forest species including medicinal plants and fruits.
- Soil conservation through terracing, gully plugging, check dams, desilting of waterholes, river site protection and plantation in degraded forests.
- Grassland management through regulated grazing and introduction of improved grasses.
- Promotion of ecotouriism by involvement of local communities in proper utilization of their natural resources.
- Social welfare through compensation for crop and other losses, organization of health camps, tribal housing and immunization of cattle.
- Education and training through awareness campaigns, distribution of publicity materials, training in handicrafts like rope making, leaf plate making and sewing.
- Improvement of infrastructure like construction of interpretation centers and field staff quarters in remote areas.

Apart from the management interventions as indicated above, a very broad range of institutions including universities, colleges, non-governmental organizations and research institutions are encouraged to formulate research projects in Biosphere Reserves, Central government provides substantial amounts for funding focused research activities in different inter-disciplinary fields for developing data on Biosphere Reserves. Some important aspects of research include monitoring of individual populations of life forms to study their response to various management interventions. Activities are

focused at two different levels : (i) landscape / ecosystem level (ii) species / landraces level.

In a recent review on Biosphere Reserves and their management, some of gaps noticed are :

- Lack of integrated knowledge on eco-geographic aspects, socio-economic aspects of local communities, political and economic factors and communication gap with local people residing in the area.
- Lack of study on the role of species in the maintenance of ecosystem health particularly in the context of response to natural and human disturbance in specific pockets.
- Inability to have authentic economic valuation of biodiversity for contributing to better scientific management. Natural resource accounting and preparation of biological resource audit for Biospheric Resources are gap areas.
- Lack of efforts for ecological rehabilitation of degraded habitats for the maintenance of biodiversity as well as the sustainable use of landscapes and species for promoting the economic benefit of the local communities.
- Need for giving greater priority to research and development in the area of ecological restoration, including propagation technique for rare endemic species.
- Need for determination of monitoring regimes including identification of indicators and frequency of monitoring for better management of Biosphere Reserves.

We have to provide inputs to evolve environmentally compatible packages suiting local cultural heritages for sustainable development. The Biosphere Reserves are expected to act as models and laboratories for generating and implementing suitable practices for benefit of people and society at large. This calls for an all out effort by all stakeholders for long term prosperity.

Chapter 6

NATURAL DISASTERS AND MITIGATION

6.1 INTRODUCTION

Natural disasters represent the dynamics of the violent forces of nature which result in catastrophic consequences for the environment affecting life and property. Earlier, natural disasters were considered as acts of God. More reasonable explanation on the instability of earth's crust is now ascribed to a multitude of ongoing processes related to chemical reactions, stress, strain, organic movement, diastrophism, glaciations, actions of wind and water, tidal effects and so on. It is now realized that these activities are governed by certain physio-chemical principles, many of which may be predictable. Calamities like earthquakes, volcanic eruptions, landslides, subsidence, flood, drought and others are but manifestations of the above process of nature (Bhatia, S.C., 1992).

TABLE 6.1.1

Primordial Origin of Natural Disasters*

S.No	Element		llustrative Disaster
1.	Sky	Ionosphere	- Meteor, Comet, Particle shower
		Stratosphere	- Thunder storm, Lightening
2.	Air	Oceanic	- Surges
		Surface	- Gale, Storm, Cyclone, Tornado, Typhoon
		Dry land	- Hot winds, Sand storms
3.	Fire	Sub-terranean	- Gaseous fireTerranean
			- Forest fire
4.	Water	Rain	- Flood Snow/ice
			- Hailstorm, Sleet Ocean
			- Tidal wave Lack of water
			- Drought
5.	Earth	Surface	- Landslide Core/mantle
			- Earthquake, Volcano

* Source: Bhata, S.C., 1992

The primary origin of natural disasters can be classified based on their origin from the five primordial elements viz. the sky, air, earth, fire and water. (Table 6.1.1)

Often hazards and disasters are used to mean the same, however, hazards pose a threat to human community, while disasters cause destruction. Re-organizing a hazard and taking preventive measures goes a long way in minimizing the losses due to any disaster. Occasionally a *disaster* is defined as an abnormal condition (natural or anthropogenic) of the environment which can exert a serious and damaging effect on human, plant and animal life beyond a certain critical level of tolerance. It is very difficult to say what is the critical level. Natural hazards range from predictable to the unpredictable, and from those caused by a single factor to those caused by many. Some of them could be traced to geological and geomorphological factors, and some to the environmental and climatic change factors (Narayan, L.R.A., 1992). The human race, through its non-sustainable activities has become a major causative factor triggering some kind of hazard at times, leading to disaster. There is a great potential in aerospace technology and particularly satellite remote sensing for monitoring global changes, and giving early warnings of natural disasters. Such studies are always multidisciplinary in character and are expected to provide valuable guidance to our planet's maintainability through sustainable development process.

Some typical hazards can be grouped as follows :

(i) Exogenous - Floods; Droughts; Landslides; Avalanches

(ii) Endogenous - Volcanism; Earthquakes

(iii) Anthropogenic - Subsidence (from activities such as underground mining); Reservoir Seismicity; Collapse of Structures (e.g., dams, dykes, bridges, buildings)

Some others could be epidemic; heat; cold wave; crop pests and diseases; forest fire; tornado etc. Each of such disaster leaves considerable after-effects and losses in human lives, animal lives, destructions to properties and so on. Some of them are very sudden, some sudden, some gradual ,while some slow and some very slow. It may be of interest to indicate here the disasters in terms of time scale and duration (Table 6.1.2)

TABLE 6.1.2

Indicative Time Scale and Duration of Disasters*

Disasters	*Time Scale*	*Duration*
Lightening	Very sudden	Seconds
Earthquakes	Very sudden	Minutes
Accidents	Very sudden	Minutes
Tornado	Sudden	Hours
Thunderstorm	Not sudden	Hour
Dust Storm	Not sudden	Hour
Hail Storm	Sudden	Hour
Forest Fires	Not sudden	Hour
Landslides	Sudden	Hours to days
Cyclones	Gradual	Days
Flash Floods	Sudden	Days
Floods	Gradual	Days to Weeks
Crop pests & diseases	Slow	Weeks
Epidemics	Very slow	Months
Drought	Very slow	Months

*Source : (Narayan, L.R.A., 1992)

Out of the above list, some disasters are preventable by taking advance actions and continuous monitoring, some are non-preventable but could be mitigated again by regular monitoring and timely assessment for design of an effective management plan. It may be noted that most of preventable disasters are generally induced by man, in some form or the other due to bad management of environment and non-sustainable development activities particularly with reference to natural resource exploitation.

Environmental problems of high Himalayan mountains are associated with its inherent fragility due to immature geology and extreme weather and climatic conditions resulting in intense freeze-thaw cycle and cloud bursts. Natural hazards in the region are therefore associated with high seismicity, climatic extremes, large snow/ice avalanches, debris flow, mud flows and debris slides, outburst from moraine dammed lakes and glacier-lake-outburst floods (GLOFs) which occur with varying intensity and frequency throughout the

mountain region, making it a high risk zone for living need special monitoring efforts.

6.2 HIGH SEISMICITY

The high seismicity (the form and status of earthquake occurrence) of the Himalayan region is rooted in its recent orogenic evolution, as a result of which Himalayas are still rising. The Himalayan province as a whole is geodynamically very active – it is prone to violent crustal movements causing earthquakes (Valdiya, K.S., 1998).

The snapping and attendant slipping of rocks on faults and thrusts have given rise to frequent earthquakes. The magnitude of seismic events had varied from moderate to high . Four major earthquakes of magnitude higher than 8 on Richter Scale had occurred in the region; Shillong (1897)- magnitude 8.7; Kangra (1905)- magnitude 8.4; Bihar (1934)- magnitude 8.1; and Assam (1950)- magnitude 8.7. Most of the damaging earthquakes in the region have shallow focal length while others ranging from a few km. to 100 km (Srivastava, H.N., 1998).

The Main Boundary Thrust (MBT – separating the Outer Himalayas from the Lesser Himalayas) and the Main Central Thrust (MCT – separating the Lesser Himalayas from the Great Himalayas) dip steeply at 30° to 40° respectively near the earth's surface but flatten out at depth. These thrusts/faults are responsible for distribution of seismicity throughout the region with a fairly high concentration between MBT and MCT. There are seismic gaps where major earthquake activity has not occurred during past 100 years and are considered as high potential areas for occurrence of future earthquakes.

It is feared that a large dam may induce occurrence of a large earthquake. So far more than nine dams have already been impounded with water with no evidence of increase in seismicity. On the other hand, a decrease with a distance of 100 km from the site after initial filling of Tarbela reservoir has been observed. In any case, the threat of likely occurrence of major earthquake has to be considered by appropriate earthquake resistant designs of structure.

The 20th October 1991 earthquake of magnitude 6.6 on the Richter Scale in the Uttarkashi-Tehri region of Garhwal (Central Himalayas) has brought havocs and perils in areas of active faults. The earthquake which violently shook a large part of north central India, originated

as a result of slipping on segments of faults in the active zone of the Main Central Thrust. However, no damage to the main foundation of Tehri dam was noticed after 1991 Uttarkashi earthquake. Surfacial cracks to the structure were not observed anywhere in the dam area and the project authorities maintained that the design features ensure the safety and integrity of the controvertial Tehri dam.

A summary of damaging earthquakes of magnitude M $\geq$ 5.0 on Richter scale that have occurred since 1987 upto 1991 is given in table 5.2.1 (Arya, A.S., 1994).

TABLE 6.2.1

Earthquake Occurrence in Indian Himalayas, M $\geq$ 5.0 (1897-1991)*

S. No	*Seismic Region*	*Number of earthquakes having magnitude(M)* 5 to 5.9	6 to 6.9	7 to 7.9	8.0 or more	*Maximum Intensity (Modified Mercalli) Scale*	*Return period observed for M $\geq$ 5.0*
1	North Western Himalayas (J&K, H.P. and sub-mountain parts of Punjab)	25	7	2	1	x	2½-3 years
2	Central Himalayas (UP/Nepal Himalaya, North Bihar)	68	28	4	1	xi	1 year
3	North East India	200	128	15	4	>x	<4 months

*Source: Arya, A.S. (1994)

4.3 CLIMATIC EXTREMES

The Himalayan region is characterized by extreme cold and arid winter conditions in the west to warm and humid summer conditions in the east with alterations of dry and moist conditions in wide range of

altitudes having different microclimates. However, the understanding of climatic extremes such as cloud bursts, hailstorms, droughts etc. which play a crucial role as environmental constraints at micro-level for agricultural production, has neither been developed or documented. Cloudbursts cause heavy damage to slope failure while hailstorms or drought inflict great losses to agriculture.

Cloudbursts occur in heavy rain-showers due to intense convective activity and occurrence of thunderstorms. These storms are only 15 to 30 km across and generally escape observation from widely spaced meteorological observatories. We need closer observation network for better definition of these storms for predictive purpose. Table 6.3.1 shows the most significant climatic extremes of heavy rainfall which are the root cause of devastating floods. The maximum observed 24 hr rainfall totals are given below They follow the same pattern in terms of spatial variation of rainfall intensity (Bruinzeel, L.A. and Bremmer, C.N., 1989)

TABLE 6.3.1

Maximum observed 24 hr. Rainfall at Selected Stations*

Station	*24 hr. rainfall (mm)*
Cherraapunji	1036
Dibrugarh	745
Darjeeling	640
Almora	221
Dehradun	152

* Source: Bruinzeel, L.A., Bremmer, C.N., (1989)

Hail is precipitation of either transparent or partly or completely opaque particles of ice (hailstones), usually spherical, conical or irregular in form and of diameter generally 5 to 50 mm, which falls from a cloud either separately or agglomerated into irregular lumps. Hail damages crops, vegetation, buildings, vehicles on direct contact. Damage is usually related to the size of hailstones. For hail suppression, silver iodide and cement have been successfully used as efficient nucleating agents. Injection of artificial nuclei in the regions of hail formation in a thunderstorm causes competition in the available water supply impeding the growth of hailstones. Small

pieces of hail melt before falling on the ground and thus containing the damages.

The troposphere – stratosphere zone is responsible for cumulus clouds where thunderstorms and lightening arise. Thunderstorms are giant disturbances taking place in water laden and electrically charged cumulominous clouds. These produce the twin effects of thunder and lightening (a high voltage electric spark). The movements of updrafts and downdrafts in clouds, at the rate of 5 meters per sec. in small storms and 70 meters per sec. in large ones, produce thunderstorms. The regions of movement are nearly two kms across. Usually, the upper part of the clouds carry positively charged particles and the lower part carry the negative charge. Giant thunderstorms produce almost continuous electric discharges at rates of 10,000 flashes per minute. An average storm may produce 5-10 flashes per minute. Electric discharges take place within the clouds and from clouds to ground. A lightening stroke is similar to an explosion, where the audible sound wave produced is the thunder.

Drought has been defined as meteorological, hydrological or agricultural. *Meteorological drought* results in a situation when there is a significant decrease from normal precipitation over an area (generally more than 25 percent). *Hydrological drought* occurs as a result of prolonged meteorological drought resulting in depletion of surface water from reservoirs, lakes, streams, rivers, cessation of spring flow and fall in groundwater levels causing severe shortage of water for livestock and human needs. *Agricultural drought* occurs when soil moisture and rainfall are inadequate during crop growing season to support healthy crop growth to maturity and cause extreme crop stress and wilt. Prolonged drought occurs in Himalayan region in rain shadow region when precipitation is already scanty. Cold and dry regions are particularly stressed for agricultural production under dry-land farming conditions. Greater technological interventions are needed for sustaining production in these regions.

6.4 SNOW AND ICE AVALANCHES

Snowfall in great Himalayan range varies from 12 to 18 m in winter months (November to April) in the western region making the region more vulnerable to snow avalanches (Upadhaya, D.S. 1995). Winter snow is smaller in eastern region with a high treeline, which restricts the avalanche activity and thus the environmental hazards.

The great Himalayan range experiences maximum number of avalanches of all types ranging from loose snow avalanche during early winter to wet slab avalanche during March-April each year.

The *avalanches* occur whenever deep snow accumulates on slopes exceeding a crucial inclination. Avalanche activity is a function of structural weakness of the snow cover over the ground and the prevailing meteorological conditions. Due to excessive snowfall, steep slopes of the mountains, strong winds and tectonic activities in Himalayas, snow avalanches occur in varying intensity and frequency. Most of the Himalayan glaciers are fed by snow avalanches from high slopy terrain in the glacier region. Sometimes contributions from these snow avalanches compare the direct snow precipitation inputs to the glacier system. Avalanched snow converts to glacier ice more quickly than the snow precipitated in the higher elevation (i.e. the accumulation zone), thus enhancing the glacier ice activity in the Himalayan region.

Study of geomorphological characteristics such as slope, aspect, terrain configuration along with snow density, settlement glide etc. are of vital significance for forecasting avalanches. Potential sites are normally studied in details integrating the available data for hazard evolution and forecast.

Snow Avalanche Study Establishment (SASE), Manali is regularly issuing avalanche forecasts and working on avalanche control structures e.g. design of formation zone control structures like snow nets, snow rakes and snow bridges. Design of snow gallery, diversionary dams and moulds have been made along Manali Leh road. We have to recognize the supporting role of natural forests as a supporting structure over the costly engineering measures and artificial structures. Where there is no forest cover ,we have to design suitable protective structures to deal with the menace.

An ice avalanche is a sudden, rapid, down-slope movement of ice following its development from the terminus of a glacier. Conditions favourable for ice avalanching are created when the terminus of a glacier retreats up a steep slope. Glacier avalanches are common in mountain areas and are hazardous. When the avalanching ice plunges into a moraine-dammed lake, it can generate waves that overtop the dam, which may trigger a catastrophic outburst (Evans, S.G. and Clague, J.J., 1992). Glacier avalanches usually occur during the summer months and result from a destruction of tensile strength

in the ice mass through progressive fragmentation associated with crevasse development, the melting of parts of the glacier may be frozen to the substrate, and the reduction of frictional resistance at the ice/rock interface due to increased water pressure. A few years back, an ice avalanche in Beas destroyed the equipments, building and other infrastructure at SASE campus, which had to be shifted near Chandigarh.

6.5 DEBRIS FLOWS, MUDFLOWS AND DEBRIS SLIDES

Debris flows, mudflows and *debris slides* are all mass movement process and could be included in one word i.e. 'mass wasting' (Gerrard, J., 1990). Mass wasting is a widespread constraint faced in all parts of the Himalayas. It describes a variety of processes through which large masses of earth material move downhill under gravity, both in slow creeping mode or as rapid landslides. Mass wasting is the most frequent and widely dispersed manifestation of the fragility of the Himalayan terrain and is basically a natural process. Human activities can substantially aggravate its impact and scale. Most important natural factors are:

- (i) Steep slope with high relative relief
- (ii) Seismicity
- (iii) Groundwater flows accentuating landslips
- (iv) Cloudbursts and intense rainfall events
- (v) Nature of the rocks (soft sedimentary, foliated metamorphic or fractured indigenous
- (vi) Toe undercutting by torrents and floods

The above factors are aggravated by anthropogenic activities e.g. loss of forest cover; extension of agriculture into steep slopes; open-cast mining without environmental control and road building without regard to geological factors.

The occurrence of landslides in mountains cannot be prevented in all cases but the damage can be reduced by taking effective control and preparedness measures for disaster management. Land hazard zoning characteristics e.g. proximity to fault, slope angle, dip slope retention, relative relief, height, nearness to ridge tops, lithology and land-cover are helpful in making decision for development projects. Large catastrophic landslides also occur specially on the slopes of the main glacially over-steepened valleys and the major gorges. These hazards are relatively rare but when they occur, they present a great risk to the population.

6.6 OUTBURSTS FROM MORAINE-DAMMED LAKES

Moraine-dammed lakes are found in high mountains close to existing glaciers. These are formed when glaciers retreated from moraines built during the Little Ice Age (LIA) and where the moraines dammed glacial streams (Evans, S.G. and Clague, J.J., 1992). Moraine dams are susceptible to failure because they are steep-sided, and relatively low width-height ratios, and consist of poorly sorted loose sediments. In addition, these dams and lakes behind them commonly occur immediately downslope from steep slopes that are prone to great avalanches and rockfalls. Moraine dams generally fail by overtopping and incision. The triggering event is most frequently a glacier avalanche from the toe of the retreating glacier which generates waves that overtop the dam. Melting of ice cores and piping are other reported failure mechanisms.

In Himalayan region, of some 3000 to 5000 m altitude over a distance of 10 to 30 km, from the main river valleys, are reflected in the steep fall of glaciers that cause these problems. On the other hand, the trunk streams of Himalayan rivers are deeply incised and fall relatively gently. Steep glacierized valley walls and tributary valleys may thus cut off extensive drainage areas. High relief, steep average fall and large climatic gradient between upper and lower reaches promote vigorous activity of ice masses in the region. This is reflected in those cases where the glacier movement is of the order of 150 to 250 m/yr. The sudden drainage of dammed lakes represents a great hydrological hazard.

6.7 GLACIER LAKE OUTBURST FLOODS (GLOFS)

Glacier-dammed lakes are found mainly at the margins of valley glaciers, although some occur within or beneath cirque and valley glaciers and mountain ice caps. Some of the largest lakes are situated in main valley dammed by tributary glaciers and at the mouths of tributary valleys blocked by trunk glaciers. These lakes may drain suddenly and rapidly by the formation and enlargement of subglacial and englacial tunnels and occasionally by overtopping, the resulting flood is termed a 'Jokulhlaups' (Evans, S.G., Clague, J.J., 1992) or glacier-lake-outburst-flood (GLOF).

Thus *GLOFs* are due to sudden outburst of water from glaciers or glacier dammed lakes. In glaciated areas, these outburst occur frequently at periodical intervals and generally have no direct

relationship with the meteorological conditions. These are primarily controlled by hydraulic considerations. A GLOF could be large enough to destroy roads, bridges or other structures and may be truly catastrophic in timing and release of water and sediment quantity for the destruction of the downstream environment. GLOF may involve several types of impounded water bodies – These may be large visible lakes in the lateral streams and valleys or lakes in the main valley dam by ice from a tributary valley or the water may be entirely below the surface of ice and not visible. These floods are normally periodical but the periodicity may vary from 1 to 10 years or even more depending on the location. The resulting hydrograph from GLOF resemble normal storm unit hydrographs except that the time scale is reversed. The flow starts at a low rate and increasing exponentially until a peak is reached then the drainage goes off abruptly. GLOFs' are poorly documented but observed to create floods raising water levels up to 100 m (Bahadur, J., 1981).

Some of the world's largest documented historical GLOFs occurred in Karakoram Himalayas. The damming of upper Shyok river by Chongkumdan glacier formed a lake (Volume $\sim 1.4 \times 10^9 m^3$). A sudden outburst of this lake occurred in 1929 and the flood wave travelled down the Shyok river into Indus, creating a rise of 8 m, 740 km downstream from the ice dam.

In Nepal, thirteen GLOFs are observed since 1960 for 30 years duration giving a very high frequency of natural hazard i.e. more than once in every three years (Yamada, T, 1992). In another investigation, a maximum GLOF discharge at the upper Arun dam-site is about three times the spillway design flood (1000 year flood) selected for the concrete structure of the run-off-river dam. Results of flood analyses (Meon, G and Schware, W., 1993) for the site are given below :

TABLE 6.7.1

Flood Flow Analyses for Upper Arun Dam Site*

Type of Flood	*Maximum DischargeM^3/s*
GLOF	6300
PMF	4400
1000 year flood	2100
100 year flood	1800

* Source : (Meon, G. and Schwarz, W., 1993)

It is considered necessary to have GLOF analysis for design flood of projects in glacier dominated watersheds. Unfortunately, little is known about the exact mechanics of outbreak of Jokulhlaups

6.8 FOREST FIRES

Forest fires (natural or man-made) are the biggest one time destroyer of natural vegetation. Forest fires could be classified (Rao, V.R. et al 1983) as under :

Ground fires

They occur with intense heat beneath the undecomposed portion of forest litter. Such fires occur at high altitude Himalayan fir and spruce forests.

Surface fires

Occurring on/or near the ground and are the commonest cause of forest fires.

Crown fires

These occur in the crown of trees and are prevalent in low level coniferous forests in Siwaliks.

Natural fires

Occur mostly due to lightning and sometimes due to rollng stones and rubbing of dry bamboos due to strong winds. Sparks from coal-fired railway locomotives could originate forest fires. These could be initiated by thrown burning match-sticks, cigarettes and bidis in the forest area.

Deliberate or intentional forest fires are also set sometimes by the villagers to catch wild animals. Fires used in collecting minor forest produce like honey may sometimes spread engulfing larger areas. Sometimes the villagers on the outskirts of the forest, set fire to the brushwood and other unwanted vegetation on their field before monsoon showers in order to enrich their fields with the ash. Controlled forest fires have beneficial effects in enriching the productivity of a forest and is also practiced in the country in the chirpine forest to prevent occurrence of more destructive accidental fires in the hot dry weather.

Biomass burning has increased with time globally and so are the

production of greenhouse gases and their release to the atmosphere has built up. The enhanced frequency of fire may prove to be an important positive feedback on a warming Earth. Biomass burning includes the combustion of living and dead material in forest, savannas and agricultural wastes, the burning of fuel wood. The percentage production of various gases (Table 6.8.1) during flaming phase(lasting for an hour or less) and the smoldering phase (lasting up to a day or more)

TABLE: 6.8.1

Percentage of Production of Gases during Flaming and Smoldering Phases of Burning Based on Laboatory Experiment*

Gases	*Percentage in Burning Stage* *Flaming*	*Smoldering*
CO_2	63	37
CO	16	84
CH_4	27	73
NMHCs	33	67
NO_X	66	34
NH_3	15	85
NCH	33	67
CH_3cl	28	72

*Source : Lobert, J.M. et.al (1991) where NMHCs stands for non-methane hydrocarbons.

There are growing incidences of forest fires over time in terms of number and area affected in the Himalayan region (Samra, J.S. et al 1999). About 2 to 15 per cent of the forest area is prone to frequent fires and 33 to 83 per cent is subjected to occasional fires (Table 6.8.2).

Unprecedented forest fires in 1995 and 1999 in western Himalayan region are indicators of the resentment by rural community to government policies. Many times, the graziers also burn the forest floor deliberately to control thorny bushes and promote growth of grasses for their livestock because they have no stake in the standing trees of the forest. Lack of transparency in the incentive to the community through equitable sharing of the produce is a big handicap

for fire fighting operations which were carried out by the villagers in the past voluntarily.

TABLE 6.8.2

Extent of Forest Fires in the Indian Himalaya*

	Forest Area Affected with Fire(%)		
States	*Frequent fires*	*Occasional fires*	*Total*
North Eastern Himalayas			
Arunachal Pradesh		68.0	68.0
Assam	15.1	80.2	95.3
Manipur		4.0	38.0
42.0			
Meghalaya	4.1	37.8	41.9
Sikkim	-	33.2	33.2
Triura	6.0	83.0	89.0
Western Himalayas			
Himachal Pradesh	6.2	37.2	43.4
Jammu & Kashmir	2.1	33.2	35.3
Uttaranchal	8.5	58.7	67.2
All India	8.9	44.2	53.1

*Source : FSI (1995)

Policy options for mitigating biomass burning have been developed e.g. marketing of timber as a resource and productivity of existing agricultural lands to reduce the need for conversions of forests to agricultural lands by addition of fertilizers, incorporate crop wastes into the soil instead of burning and replace animal grazing by stall feeding.

6.9 MITIGATION OF NATURAL HAZARDS

Natural hazards e.g. snow avalanches, rock falls debris flows, Landslides, torrents, floods have multiple identification criteria for mapping and field observations as identified by Gardner, J.S. et al 1992, are listed in Table 6.9.1.

Deaths and suffering from natural disasters are closely related to poverty. Ninety five per cent of disaster-related deaths occur among two-thirds of the world's population that occupy developing countries including India. It may be relevant to point out that the following observations formed the impetus to the International Decade for

Natural Disaster Reduction (IDNDR) launched in the 1990s (Elo, Olavi, 1994).

TABLE 6.9.1

Multiple Hazard Identification

Process	*Photograph & Map Criteria*	*Field Criteria*
Snow Avalanche	slope gradient of greater than 30 degreesspecific slope morphology: size of starting zone, steepness, smoothness and simplicity of the track, confined v.s. unconfined path, areaaspects of dominant winds and insolation probable type of avalanchedamage to or changes in forest covererosional features, such as gullies and couloirs depositional features, such as debris (rock timber) and avalanche conesman-made control or protection structures	see photography and map criteria evidence of avalanche type: damage to vegetation, and amount of debris, if anyevidence of avalanche frequency: damage to vegetation, type of vegetation cover, evidence of avalanche extent: damage to vegetation, changes in vegetation, debris local official and residences
Rockfall	steep or barren cliffs that rise above less steep talus or colluvial slopestalus slopes and areas adjacent to it occupied by larger angular randomly oriented rocks.changes in vegetative cover	see photography and map criteriaactive rock fall areas may show rock displaced or damaged vegetation, fresh 'tracks' of rocks rolling downslope, fresh scars on cliffs, anomalous or disoriented lichen growth on rock blocks damage to man-made featuresless active rockfall areas may be partially overgrown with vegetationrock diphighly fractured face
Debris flow	usually located in the	see photography and map

(Contd.)

(Table 6.9.1 contd.)

Process	Photograph & Map Criteria	Field Criteria
	lower parts of tributary streams of major streams as they enter the major valleyvegetative cover can indicate recent activity or inactivity debris flow deposits, e.g. levees and the undulating topography of fans debris flow fans are characteri-zed by undulating topo-graphy disturbed vegeta-tion, location near mountain fronts, multi-plicity of small stream channels, and a fan shape source area, steep slope, unconsoli-dated surficial material, usually denuded of vegetation possible source of large volumes of water, e.g. glacial iceartificial controls	criteriaheterogeneous deposits,which are a mixture of mud, angular pebble to boulder size or layer rocks, soil vegetation, and coarse debris of trees deposi-tional land forms and features such as debris-laden streams channels, leaves, levees, debris flow fans areas of disturbed vegetation boulder trains or isolated boulders in between channelswidely ranging debris size
Landslide	Change in valley profile, e.g. valley is usually narrower at the slide-presence of large blocks of unconsolidated material, giving hummcky topography-poor drainage, some pondingerratic drainage patterns, or irregularity along shorelinelobate form with steep distal rimsteep scarp facetrees growing in disarray at divergent angles displaced cultural features, especially roads	see photography and map criteriadamage to vege-tation, including titled or bent treesundulating sur-face, perhaps overgrown
Torrent potential	source of water: glacial ice, areas favourable for	see photography and map criteriarock and

(Contd.)

(Table 6.9.1 Contd.)

Process	*Photograph & Map Criteria*	*Field Criteria*
	snow accumulation, and areas susceptible to high overland flow, i.e. steep, unvegetated slopessteep gradient to channel profile undercutting of banks, resulting in slope failureareas of alluvial deposits, i.e. alluvial fan at the entrance to main valley	timber debris in channelchannel wider than necessary for normal stream flow areas of overbank spillage and "washed ground"damage to vegetation artificial controls
Flood level	Ground surrounding a river, extending to significant change slopealluvial deposits i.e. unconsolidated super-ficial material nearby a river course erosional and deposi-tional features of recent river courses, e.g. meander scars, oxbows, fans etc. vegetative cover, e.g. grass and shrub communities and lack of trees.	see photograph and map criteriadisrupted or damaged vegetation washed ground

*Source: Gardner, J.S. et al (1992)

(i) The extent of loss of lives, physical damage and economic costs caused by disasters; their overall impact has often become an unbearable burden both on the stricken locations and on the socio-economic development process of vulnerable countries.

(ii) The availability in today's world of a wealth of scientific knowledge and technological know-how, already used in other sectors, that could be transferred and applied to the reduction of the overall impact of disasters on society.

The following objectives were adopted by the UN General Assembly

(1) The objective of the decade to reduce through concerted

international action, especially in developing countries, the loss of life, property damage and social and economic disruption caused by natural disasters, such as earthquakes, windstorms, tsunamis, floods, landslides, volcanic eruptions, wildfire, grasshopper and locust infestations, drought and desertification and other calamities of natural origin.

(2) The goals of the Decade are :

(a) To improve the capacity of each country to mitigate the effects of natural disasters expeditiously and effectively, paying special attention to assisting developing countries in the assessment of disasters damage potential and in the establishment of early warning systems and disaster-resistant structures when and where needed;

(b) To devise appropriate guidelines and strategies for applying existing scientific and technical knowledge taking into account the cultural and economic diversity among nations :

(c) To foster scientific and engineering endeavours aimed at closing critical gaps in knowledge in order to reduce loss of life and property

(d) To disseminate existing and new technical information related to measures for the assessment, prediction and mitigation of natural disasters,

(e) To develop measures for the assessment, prediction, prevention and mitigation of natural disasters through programmes of technical assistance and technology transfer, demonstration projects, and education and training, tailored to specific disasters and locations, and to evaluate the effectiveness of those programme.

From Indian point of view, three broad areas for concentrated effort to reduce the impact of natural disasters are research; public education; and infrastructure for post-disaster relief. We shall briefly discuss these elements.

Applied science and technology have already provided means to predict some natural disasters with a reasonable degree of accuracy; but more research is needed to develop new techniques to predict the natural disasters well in advance and preferably, even to prevent their

occurrence. Various government and private research organizations and universities should chalk out new research programmes to study natural hazards. Since the financial resources of research organizations are severely limited, the possibility of funding natural hazard research programme from other sources, e.g., insurance companies, private industries and international agencies should be explored.

Once the steps have been taken to predict natural disasters, it is equally or even more important to warn the public well in advance and also to create an awareness as to how to reduce the impact of impending natural disasters. When a disaster is likely to occur, the public should be warned through radio, TV and other address system and advised to move to safer areas. Documentary and educational films on disaster mitigation may be produced and shown on TV.

The purpose of reducing the impact of natural disasters can hardly be achieved unless the efforts are organized and coordinated in a planned manner, and hence the critical importance of appropriate infrastructure. In the country, the District Collector has the overall responsibility of administering the district. Thus, it is desirable that the District Collector should organize "Rescue Teams" well in advance. These teams may consist of Specialists from the Fire Brigade, Civil Defense, Police Department and Voluntary organizations. Warehouses may be established to stock goods, food items and medical supplies. Larger industrial houses may develop their own corporate disaster preparedness plans. Disaster prevention and preparedness should be viewed as a long-term investment.

Space technology has played an effective role in earth and atmospheric studies for last three decades. This is due to the unique ability of space platforms to provide a synoptic view of the earth's system in the entire electromagnetic spectrum. Space systems, which drive their basic advantage from the altitude of their operation, unaffected by natural disasters, have become a most valuable tool in disaster management (Rao, U.R., 1994). The inputs from satellites have unambiguously demonstrated their capability in providing vital information and services towards all the three major aspects of disaster management namely prevention, preparedness and mitigation. The unique capabilities of remote sensing satellites to provide comprehensive, synoptic and multi-temporal coverage of large areas at frequent intervals with a quick turn around time, have been valuable in continuous monitoring of atmospheric as well as surface parameters

related to natural disasters. The vast capabilities of communication satellites are now available for dissemination of information and early warning, data transfer and real time coordination of relief operations. The advent of Very Small Aperture Terminals (VSATs), Ultra-Small Aperture Terminals (USATs) and phased array antennas have further enhanced the capability.Satellite based remote sensing inputs are key to sustainable development (SD) at micro level. Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The critical objectives of SD are reviving growth; changing the quality of growth; meeting essential needs for job, food, energy, water and sanitation; ensuring sustainability level of population; conserving and enhancing the resource base; reorienting technology and managing risk; merging environment and economies in decision making; reorienting international economic relations and making development more participatory. SD has to be based on maintaining the fragile balance between productivity function and conservation practices through constant monitoring and identification of problem areas which require application of alternate agricultural practices, crop rotation, use of bio-fertilizers, integrated pest management, energy efficient farming methods and reclamation of underutilized degraded lands. It calls for the up-gradation of various renewable and non-renewable resources, characterization of coherent zones of agricultural identities and identification of constraints / ecological problems at micro level instead of the present practice of beneficiary oriented, arbitrary, sectoral approach. Satellite based remote sensing inputs are the key to initiate integrated sustainable development.

Geographical Information Systems (GISs) are computer systems for the inputs, storage, analysis and display of spatial data. GISs are tools that provide functions to digitize maps, or capture image data, to design and build data bases, to apply spatial analysis to display or output results as maps, reports, images and other digital products. These tools are very helpful in solving complex problems connected with the planning and management of natural resources.

Global Positioning Systems (GPSs) are a method of automatic spatial data logging, originally pioneered for navigation and military use. A constellation of NAVSTAR satellites permits the use of a GPS receiver to calculate observers' position on the earth's surface

to an accuracy of within one meter. Altitudes can be recorded. A GPS logger can be connected to a PC for direct data input to a GIS, GPS technology is not suitable for data capture in large study areas. One essential prerequisite for the use of GPS is a clear field of view, since it is necessary for the GPS receiver to fix its position from at least four of the NAVSTAR satellites. This situation ensures that both geographical location and height are fixed to the best accuracy. However, locking on to four satellites in a mountain terrain is often problematic when working in confined areas e.g. deep valleys or forested slopes.

The combined use of GIS, digital image processing and simulation models provide new possibilities for better environmental monitoring, forecasting and management for wider areas within a limited time.

In the country, the Disaster Management Network include Cabinet Committee which directs the National Crisis Management Committee. The Central Relief Commissioner (under the Ministry of Agriculture) reviews the contingency plans drawn by other ministries and departments for relief operations. In 1995, a National Centre for Disaster Management (NCDM) has been established at Indian Institute of Public Administration (IIPA) at New Delhi, to prepare an exhaustive information base on damages and resources spent on mitigation practices. The centre would conduct research in areas of disaster preparedness, mitigation, cost analysis and environmental impact assessment of various disasters, seeking participation and interdisciplinary cooperation of various government agencies and voluntary organizations (Sharma, V.K., 1999).

Chapter 7

SOCIO-ECONOMIC ASPECTS

7.1 INTRODUCTION

Earlier, we have discussed the sustainability concept of the Rio 1992 declaration for the mountain areas outlining the three components viz. ecology , economy and social issues. The underlying values of the three components must be realized to the highest measure possible.

In general, mountain inhabitants live in remote isolation and are deprived of most of the infrastructural, socio-economic and technological advancements. In the past, communities had evolved production systems keeping a balance between the carrying capacity of the environment and human needs through centuries of experimentation and adoption. These indigenous systems developed harmony with marginalized natural resources on a long term basis (Samra, J.S. et al, 1999). Himalayan population is primarily composed of immigrants from different places who settled here centuries ago. Each group lived within its territory and followed the cultural and traditional dictates of their social head, called as King, Lal or Sardar. Thus, the Himalayas have become a house of tribes with diverse culture and ethnicity.

In the absence of basic amenities and poor resource position, the people worked hard for their survival and were loyal to the head of village or tribe. Many a times, there were ferocious fights between wild animals and people or even among the tribes. The hill people are generally sturdy, honest, straightforward and cooperative by nature. Total human population in the Indian Himalayas is about 34 million, of which, nearly one third is in the active working age group. Men perform all arduous tasks, while women devote labour for relatively easy works. High rate of unemployment and under-employment is due to low literacy, lack of communication and poor entrepreneurship. This ultimately has led to out-migration of male workforce from the mountains to the plains in search of gainful

employment. In these mountain societies, the inheritance ranges from patriarchal to matriarchal and the institution of marriage from polygamy to polyandry. The other important socio-economic characteristics of the mountain ecosystems are :

(i) Open access to common property resources (CPRs) which are collectively owned by the community. The river systems, forests, grasslands, fish, wild animals and even agricultural land in many parts of the NEH region fall under this category.

(ii) Natural resources are managed through people's participation and local initiatives. Creation and nurturing of appropriate and innovative local institutions is rooted in the great values of justice, equity and mutual support.

It may be noted that the sustainable and equitable use and management of natural resources require an appropriate and balanced distribution of rights, powers and duties among all stakeholders associated with these resources. In other words, a conceptual, functional and creative balance accommodating entitlements, empowerment and obligations has to be achieved (Vani, M.S., 2000).

The statutes relating to natural resources in the country, beginning with the Constitution, present a fractured or disintegrated approach to the environment. They promote conflicting interests and provide for inappropriate and unsustainable value systems and mechanisms for natural resource management. Customary legal frameworks continue to have the potential to enable community of interests and decentralized management of resources. However, the adverse impact of formal law and environmental changes has everywhere eroded their capacity to offer functional, alternative approaches to natural resource management. With the support of enabling legislation, community based legal systems may succeed in reversing environmental degradation, while at the same time eradicate poverty through ensuring equity. It is a uphill task till there is all-out effort to arrest the degeneration of the fragile Himalayan ecosystem and evolve participatory approaches that help the development of mountain agriculture, having a vast potential, yet to be realized. Some of the major socio-economic problems are dealt in the following section.

7.2 SOME SOCIO-ECONOMIC PROBLEMS

There are acute problems of under-employment, poor education, poor communication, poor transport facilities and inadequate medical

facilities in most of the Himalayan region. All these aggravate the misery and poverty of its inhabitants. Some of the socio-economic problems are degradation of common property resources (CPRs), food insecurity, migration of male working population, poor technical, and management skill, structural and attitudinal conditions of social set up, local institutions and women organizations.

7.2.1 Degradation of Common Property Resources (CPRs)

Small land holdings enhance peoples depending on CPRs. Their rapid decline and degradation, call for their rehabilitation and development to ensure their invaluable contributions to rural household economy. There are several examples where the communities have protected, maintained and productively used CPRs. Understanding these exceptions and building upon their rationale, methods and successes can help in designing development approach for CPRs (Jodha, N.S., 2000). A special programme under social forestry was launched in the mid-seventies to develop woodlots near the villages to meet their requirements of fodder, fuel-wood and fibre, and thereby ease burden on the reserve forest. For this purpose, a piece of forest located near the village was allotted to the village community after some initial investment. However, due to absence of planning, lack of funds and poor cooperation, these lands have been converted to wastelands (Samra, J.S. et al, 1999).

7.2.2 Food Insecurity

In the mountains, farmers grow different crops under varied micro-topo-sequences to achieve self-sufficiency in food grain production. In this process they cultivate maximum possible area for food crops. In absence of suitable crop production technologies suited to micro-farming conditions, the farmers operate their farm at a subsistence level. Consequently, the marginal agricultural land turns into wasteland. This forces them to compensate the loss by extending cultivation to new areas which are also not suitable for crop production, trapping them into a vicious erosion-poverty cycle. It is not possible to achieve sustainable development under these situations of deteriorating natural resource base and extreme conditions of poverty.

7.2.3 Migration of Male Working Population

Male working population from the mountains migrates to the adjoining plain areas to search gainful employment due to insufficiency of food grain and non-availability of off-farm employment opportunities in the region. The migrated family members contribute money for sustenance of the families residing in the villages. This is commonly known as *Money Order Economy*. The economic condition of hill farmers is so poor that they are hardly able to meet their minimum basic requirements. They are left with meager financial resource to invest in the production process or to address other domestic problems (Samra, J.S. et al., 1999).

7.2.4 Poor Technical and Management Skill

Literacy is poor particularly among women in the Himalayan region. As women are the backbone of hill agriculture besides their household functions, lack of their education becomes a barrier for training and adopting improved farming techniques and integrate new opportunities in the existing farming system for improvement.

7.2.5 Structural and Attitudinal Conditions of Social Set-up

Farmers do not operate as independent decision makers but are subjected to a variety of external forces, such as attitude and structure of overall population, society and government policies. Economic development is governed by the market forces which favour individuals more than social considerations. In the era of rapid economic growth, there is an attitudinal change in the society where higher priority is assigned to the individual than social goals. This initiates the process of weathering out of old traditional social ties. Further, advancement of government interventions directly or indirectly savage the punctured social informal structures (Samra, J.S. et al., 1999).m

7.2.6 Local Institutions

A large number of non-statutory village or local institutions, such as self-help groups or community-based organizations are parallel and alternative mechanisms of community empowerment. Some government departments are assuming a greater role of these voluntary institutions in rural development through community participation. Working sphere of these local institutions varies from a part of the

village, such as field management committee and Guhl management samiti to the whole village like *Van Panchayat, Mahila*, and *Yuwak Mangal Dal.* Sometimes, these institutions even cut across village or Panchayat boundaries, such as multipurpose cooperative societies, watershed management societies *Pani Panchayat, Women Dairy Cooperative* and *Gram Swaraj Mandal*. Feedback indicates a mixed response to these policy initiatives. Joint signing of cheque and payment up to Rs.10,000/- by the watershed committee has stimulated a sense of participation and accountability among the farmers. These new paradigms are emerging as a reaction product of the change political and socio-economic scenario, and their success will depend upon the real contents of the institutions.

Supply-driven and top-down development efforts based on the principle of *'I manage and you do'* yielded spectacular but short-lived results. It stimulated the process of eroding confidence between service provider and beneficiaries as well as ailing societal institutions, leading to unsustainable development. Transparent, equitable and demand-driven actions of community empowerment are sought to be a means for development in perpetuity. The Panchayati Raj Act empowers the village level elected institutions as statutory bodies to propagate the ideology of *'We manage and we do'*. Under this act, all developmental works and funds generated from community resources are vested with the village panchayat. Quality of control and management of CPRs cause new conflicts between local institutions and village councils leading to poor management.

7.2.7 Women Organisations and Empowerment

In general, women, half of the humanity have suffered discrimination and disability all over the world. The process of democratization across the countries broke down the shackles of women and brought many changes in the social, economic, and political position of women. There, however, remain the vexatious vestiges of the past, inhibiting equalitarian measures from demonstrating their true strength. International efforts through several conferences have contributed to the progressive strengthening of legal, economic, social and political dimensions of gender equality through women's empowerment. Policy perspective outlined in world conferences on women have led to the gender justice and gender equity in all spheres. The world now stands committed to the advancement of gender

equality; the establishment of mechanisms for women's equal participation and equitable representation at all level of political process; promotion of women's potential through education, skill development and employment; elimination of poverty, illiteracy and ill-health among women; and strengthening of policies and programmes that improve, ensure and broaden their access to resources needed for the full exercise of their fundamental rights.

Analysing the roots of gender disparity in Garhwal Himalaya (Nautiyal, A and Singh, D., 2001), it is observed that the proportion of rural women is generally higher and is basically due to out-migration of male population. Lack of education further adds to their pathetic condition. Though they form the backbone of Garhwal economy, they face hardships and drudgery . Factors responsible for low status in Garhwal Himalayas to promote women empowerment are listed (Table 7.2.7.1).

TABLE 7.2.7.1

Factors Governing Women's Empowerment In The Hill Areas

What the Women Possess	*What the Women Lack*	*Ways to Promote Women's Empowerment in Hill Areas*
Traditional Knowledge Base	Control of resource Base	Access for Basic and Higher Education and Control of Resources
Capacity for family Coordination	Social Status and Economic	Independence Identification of Priorities and Economic Independence
Stress Tolerance	Lack of Accessibility	Technology Base Training and Development
High Intellectual level	Lack of Equal Opportunities and Mobility	Equal Opportunities and Maximum Participation in Community Development work
Leadership Traits	Social Stigmas and Taboos	Open Mindedness
Kind Heartedness	Firm Determination, Self Esteem	Cultivation of Strong will power and Self Esteem

Source : Nautiyal, A and Singh D, 2001

Women in the hills are hard working. They toil in all economic as well as non-economic activities for the survival of their families. Out-migration of male working force from the area compels them to take on all the jobs relating to household, crop husbandry, dairy and marketing. Women are drudged in various domestic affairs and hardly get time to organize themselves. They become the first victims of degradation of natural resources and devaluation of cultural and social heritage. They are often required to travel long distances for collection of water, fodder, fuel-wood and other minor forest products for meeting their domestic requirements (Samra, J.S., et al 1999).

The participation of women in most of the community-based organizations was almost nil till mid-eighties. Several education campaigns, introduction of new public relation initiatives, electoral policies and awareness camps have increased participation of rural women in social and political institutions. Women organizations are strong in fighting against maladies, such as deforestation and liquor consumption. They are now actively participating in afforestation programme, dairy development and self-help organizations such as *Garema, Gram Samaj,* women cooperatives and *Mahila Mangal Dal.* Their larger participation shall bring out socio-economic transformation of the region.

Chapter 8

RESOURCE MONITORING, INSTITUTIONAL INFRASTRUCTURE AND POLICY ISSUES

8.1 RESOURCE MONITORING

In earlier chapters an attempt has been made to deal separately with atmospheric, geospheric and biospheric aspects which are interdependent entities of a given environment Some details of the Himalayan environment and its natural resources are included in various subsections. Himalayas, as discussed before, are home to unique ecosystems, plants, animals and other organisms. The region is endowed with the highest ethnic and cultural diversity. Biodiversity in the region is being lost at all levels, from genes in populations within specifics to habitats and communities.

In general, natural resources could be divided into two categories viz. geophysical e.g., land, water and climate and biological e.g., people, livestock and other flora and fauna (Anon, 1992). Bio-geophysical monitoring of the most sensitive, dynamic and fragile of Himalayan environment is needed for sustainable development of its agro-ecosystems. Three cardinal principles to all ecosystems are (i) the cycling of nutrients; (ii) the dependence upon an active source of energy, and (iii) a specific relationship between plants and animals, called ecosystem structure. In other words, an ecosystem is a grouping of organisms that interact with each other and their environment in such a way as to perpetuate the grouping. A group of organisms can only perpetuate itself as long as the structure is maintained that enables the energy flow and nutrient cycling.

Geological instability, interacting with a complex problem including population pressure, deforestation, landslides, erosion, water scarcity, out-migration and poverty manifest fragility to the Himalayan ecosystem. Despite all these problems apparent as degradation of

Himalayan environment and poor level of living of its people, the region encompasses several 'resource rich spots'

The region does enjoy monopoly in the production of virus-free potato tubers, temperate fruits particularly apples, and several other high value cultivated as well as wild, crops which provide scope for designing alternatives or complements to traditional agriculture as an instrument for development in the region.

The causes and consequences, underlying the increased deficits in resource demand-supply potential are many and varied. The consequences, social, economic or ecological, apparent at local, regional or global level, are to be taken as challenges by scientists, planners and administrators. Himalaya, on account of being highly diverse when characterized in terms of physical, biological and socio-economic parameters, demands a priority of actions for development planning which is distinct from other regions of the country.

Despite the apparent differences in the organization of diverse ecosystems all have a commonality in that all are dependent upon forest based inputs for their sustenance. Increasing population pressure for enhanced food production has set in a trend of declining agricultural productivity and efficiency of production. Forests are not in good condition due to overgrazing which prevents regeneration. Runoff from chir-pine forests is far greater than from broad-leaved forests in good condition. Grass cover in good condition is as effective (if not more so) as broad-leaved forests as a check of run-off, and gives a clear run-off i.e. less silt.

Lack of representative observational data for problems like denudation, siltation, hydrological imbalances suffer from drawbacks including generalized surveys and tremendous extrapolation of site-specific observations to large heterogeneous areas.

What is needed is to appreciate the positive points of traditional resource production and use systems and strengthen them through scientific and technological inputs for further improvement in their values and efficiency instead of advocating abrupt changes involving replacement of traditional systems by new ones found suitable elsewhere and carrying a big question mark in the context of hills.

It has been observed that the Himalayan environment of Indian region is changing very rapidly as is evident from water resource distribution and a number of hydrological indicators; reduced snowfall; receding glaciers; reduced rainwater infiltration capability of land; accelerated overland flow with the associated catastrophic

floods and fastened land erosion; diminishing discharges of springs and their disappearance; decreasing trend of base flows of streams/ rivers; rapidly dwindling water holding capacities of lakes and their reduction or disappearance and indeed noticeable micro-climatic changes over a period of time and reduction in biomass production i.e. site desertification.

Data on climate, soils, geological features, human settlements, needs to be integrated with biological data to gain insight into the distribution of biodiversity in the context of physical parameters and human population.. The geographical information system (GIS) can be used to analyze changes in biodiversity and land-use patterns to identify geographical locations habitats, communities and species that are subject to rapid change and vulnerable to extinction and to provide a basis for monitoring biodiversity. An action plan to enhance the conservation and management of biodiversity in the Himalayas has been outlined. (Bawa, K.S. 1993) detailing research and education aspects. The programme contains two main components : a research and monitoring to assess the current status and rate of loss of Himalayan biodiversity, coupled with plans to evaluate human needs for biomass, reduce anthropogenic threats, change in government policies and inform the public of the value of biodiversity. To be effective, the programme must first address human use of Himalayan biota; if human needs are not met, depletion of biological diversity will inevitably continue. Such a comprehensive programme would require new mechanisms of cooperation among the existing institutions. With the help of GIS, it is now possible to integrate biophysical and socio-economic data. GIS has become a powerful and dynamic tool for decision makers in preparing alternative policies and strategies for sustainable and integrated mountain development.

Collecting information and developing a digital data base for the region are major functions of ICIMODs Mountain Environment and Natural Resources Information Service (MENRIS). All information procured from official government sources and through interpretation of satellite imagery. A comprehensive GIS data base on a scale of 1:250,000 has been completed and is available in both hard copy and digital format. A number of important features are already on a scale 1: 1 million (Messerli, B and Ives, J.D., 1997).

The following are the main thematic areas for research in the mountain region :

- Climatic oscillations and extreme events

- Geological fragility and risk management
- Population and land-use dynamics
- Depletion of natural resource base and land use changes.
- Natural ecosystem degradation and desertification
- Hydrological changes linked to land-use changes and its implications for biological resource base under monsoon climatic regions
- Biodiversity monitoring and ecosystem functioning
- Complexity in human managed ecosystems and their ecological and socio-economic significance.
- Economic and technological changes and mountain communities.
- Highland – lowland interactions
- Appropriate institutional mechanisms for effective management of natural resources in the context of conflicting demands and peoples participation.

Land-use dynamics is of focal concern for sustainable development of natural resources of the mountains. By altering ecosystem complexity in a variety of different ways ranging from the sub-specific, through species, ecosystems and landscapes levels at local and regional scale (Ramakrishnan, P.S. 1991, 1992).land-use dynamics could impact upon sustainable livelihood concerns and local communities. On a global scale, it would have implications for changes, occurring in biogeochemical cycles of the earth, atmospheric levels of greenhouse and other trace gases.

To improve data base and better understand the interdependence of atmospheric processes on geosphere and biosphere in Himalayan region, the Himalayan Experiment (HIMEX) was suggested as a thrust area activity (Bahadur, J., 1995) with regional and international cooperation.

Data bases will help develop models to improve our day-to-day understanding of physical processes and direct interaction with data and analysis models without reference to experts and spatial decision support system (SDSS) at both farm and policy level through direct interaction with data and analysis models without reference to experts and researchers .Examination of scientific priorities for the International Geosphere Biosphere Programme (IGBP) reveals a requirement for global land data set in several of its core projects.

These data sets need to be at several space and time scales. Requirements are demonstrated for the regular acquisition of data at spatial resolution approximately 1 km are sensed by the Advanced Very High Resolution Radiometer(AVHRR). But they have not been available in a single archive. It is proposed that a global data set of the land surface is created from remote sensed data from the AVHRR with a spatial resolution of 1 km and should be generated at least once every 10days for the entire globe (Townshend, J.R.G., et al 1994). The high volume of the data set will present substantial challenges to users who wish to use the complete global data set in a multi-temporal form.

The conceptual course of action in the R&D programme must attempt on development of integrated development packages:

- A thorough and objective quantification of resource base and problems;
- Knowledge and application of in-hand science and technology to rejuvenate the degraded areas;
- Undertaking research to refine the science / technology relevant to restoration; and
- Ways and means to motivate people to understand the problems, their far-reaching consequences and to seek their participation towards the problem solution.

In addition there will be need for anticipatory research in areas such as the following :

(a) Renewable Energy Sources
(b) Consumer Preferences
(c) Packaging and Marketing
(d) Adoption of Bioechnology
(e) Computer Simulation

A back-up consortium of Govt. Departments, and technical institutions and universities should be formed to provide the necessary technical guidance and oversight the programme. (Swaminathan, M.S, 1991)

8.2 INSTITUTIONAL INFRASTRUCTURE

Institutions and organizations have been established since eighteenth century in the Indian Himalayan Region. Some of the earlier important institutions are given below with the year of establishment, change of name and shifting of the locations:

- Survey of India at Dehradun in 1767
- Forest College at Dehradun in1873 (later known as Forest Research Institute – FRI in 1906)
- Imperial Bacteriological Laboratory, Pune in 1893 (shifted to Mukteshwar in Uttaranchal)
- Vivekananda Laboratory at Almora for agricultural research in 1936 (adopted by ICAR in 1974 and renamed as Vivekananda Parvatiya Krishi Anusandhan Shala).
- The Central Potato Research Institute at Patna in1949 with three research stations at Kufri, Shimla and Bhowah (shifted its headquarters to Shimla in 1956) and adopted by ICAR in 1966.
- Soil Conservation Research, Demonstration and Training Centre at Dehradun in1954 and at Chandigarh in 1957 (adopted by ICAR – in 1974) under the umbrella of Central Soil and Water Conservation Research and Training Institute (CSWCRTI) at Dehradun
- Govind Ballabh Pant University of Agriculture and Technology (GBUA & T), Pantnagar in 1960 (Hill campus was set up in 1978 at Ranichauri)

The list of Universities (General and Agricultural) ; ICAR Institutes and other R&D Institutions and organizations in the Himalayan Region are given in tables 8.2.1, 8.2.2 and 8.2.3 respectively.

TABLE 8.2.1

List of Universities (General and Agricultural) in the Himalayan Region

Sl.No.	*Name*	*Place*	*State*
(a) General Universities			
1.	University of Jammu	Jammu	Jammu & Kashmir
2.	University of Kashmir	Srinagar	Jammu & Kashmir
3.	Himachal Pradesh Univesity	Shimla	Himachal Pradesh
4.	H.N. Bahuguna Garhwal Univesity	Srinagar	Uttaranchal
5.	Kumaon University	Nainital	Uttaranchal
6.	Manipur University	Imphal	Manipur
7.	Nagaland University	Lumani	Nagaland
8.	North-Eastern Hill University	Shillong	Meghalaya
9.	Tripura University	Agartala	Tripura
10.	Arunachal Pradesh University	Itanagar	Arunachal Pradesh

(Contd.)

(Table 8.2.1 contd.)

Sl.No.	Name	Place	State
(b) Agricultural Universities			
1.	G.B.Pant University of Agriculture and Technology (With Regional Research Stations at Ranichauri, Majhera, Nainital, Sui, Pithoragarh, Pauri)	Pantnagar	Uttaranchal
2.	H.P. Krishi Vishvavidyala (With Regional Research Stations at Dhaulakuan, Akrot, Berthin, Bajaura, Malan, Katrain, Sundernagar, Kangra, Nagrota, Salooni, Kukumseri, Leo, Lari, Sangla)	Palampur	Himachal Pradesh
3.	Sher-e-Kashmir University of Srinagar Jammu & Kashmir Agri-cultural Sciences and Technology (With Regional Research Stations at R.S.Pura, Udheywalla, Dhiansar, Raya, Ponichak, Samba, Rajouri, Punch, Gauri, Sartangal, Kishtwar, Shalimar, Habbal, Karewa, Shuhama, Mirgund, Khudwani, Balpora, Pahalgam, Larnoo, Manasbal, Wadoora, Konibal, Leh, Kargil).	Srinagar	Jammu & Kashmir
4.	Dr. Y.S. Parmar Univesity of Horticulture and Forestry (With Regional Research Stations at Jachh, Dhaulakuan, Nagrota Bagwan, Mashobra, Kotkhai, Sharbo, Tabo, Kalpa, Bajaura, Seobagh, Katrain, Kahla, Kandaghat, Solan, Seobagh, Bajaura)	Nauni, Solan	Himachal Pradesh
5.	Punjab Agricultural University (With Regional Research Station at Ballowal Saunkhri)	Ludhiana	Punjab
6.	Assam Agricultural University (With Regional Reearch Station at Diphu.)	Gauhati	Assam
7.	Central Agricultural University	Imphal	Manipur

(Contd.)

(Table 8.2.1 contd.)

*Sl.No.	Name	Place	State
8.	Bidhan Chandra Krishi Vishva Vidyalaya (With Regional Research Station at Kalimpong)	Mohanpur	West Bengal

TABLE 8.2.2

ICAR Institutes and Other R&D Institutions and Organizations

Sl.No.	Name	Place	State
1.	Central Soil and Water Conservation Research and Training Institute (Research Centre at Chandigarh)	Dehradun	Uttaranchal
2.	Central Institute for Temperate Horticulture (Research Centre at Mukteswar)	Srinagar	Jammu & Kashmir
3.	Central Potato Research Institute (Research Centres at Shillong, Kupi-Fagn, and Darjeeling)	Shimla	Himachal Pradesh
4.	ICAR – Research Complex for NEH – Region {Research centres at Basar (Arunachal Pradesh) Tadong, Imphal, Kolasib, (Sikkim) (Mankipur) (Mizoram), Lumbucherra (Tripura), Medziphema (Nagaland)	Barapani	Meghalaya
5.	National Brueau of Plant Genetic Resources (Research Centres at Shillong, Shimla, Bhowali, Srinagar)	New Delhi	Delhi
6.	Vivekananda Parvatya Krishi Anusandhan Shala	Almora	Uttaranchal
7.	Indian Agricultural Research Institute (Research Centres at Shimla, Tutikandi, Shimla, Katrain, Kullu)	New Delhi	Delhi
8.	Indian Grassland and Fodder Research Institute (Research Centres at Palampur)	Jhansi	Uttar Pradesh

(Contd.)

(Table 8.2.2 contd.)

Sl.No.	Name	Place	State
9.	Directorate of Wheat Research Centre	Flowerdale Shimla	Himachal Pradesh
10.	National Centre for Mushroom Research and Training	Solan	Himachal Pradesh
11.	National Research Centre for Orchids	Gangtok	Sikkim
12.	Nainitial Research Centre on Cold Water	Bhimtal Fisheries	Uttaranchal
13.	National Research Centre for Mithun	Kohima	Nagaland
14.	Indian Veterinary Research Institute (Research Centres at Palampur, Mukteshwar)	Izatnagar	Uttar Pradesh
15.	Central Sheep and Wool Research Institute Research Centre	Gassa, Kullu	Himachal Pradesh
16.	National Research Centre for Yak	Dirang	Arunachal Pradesh
17.	Indian Council of Forestry Research Research and Education	Dehradun	Uttaranchal
18.	Forest Research Institute	Dehradun	Uttaranchal
19.	Temperate Forest Research Institute	Shimla	Himachal Pradesh
20.	State Forest Research Institute	Itanagar	Arunachal Pradesh
21.	Forest Survey of India	Dehradun	Uttaranchal
22.	Wild Life Institute	Dehradun	Uttaranchal
23.	Wadia Institute of Himalayan Geology	Dehradun	Uttaranchal
24.	Indian Institute of Remote Sensing	Dehradun	Uttaranchal
25.	GB Pant Institute of Himalayan Environment and Development	Almora	Uttaranchal
26.	Himalayan Institute of Mountaineering Branches -	Manali Uttarkashi Darjeeling	Himachal Pradesh Uttaranchal West Bengal
27.	Institute of Himalayan Bio-Resources Technology	Palampur	Himachal Pradesh
28.	Indian Institute of Petroleum	Dehradun	Uttaranchal
29.	Regional Research Laboratory	Jammu	Jammu & Kashmir

(Contd.)

(Table 8.2.2 contd.)

Sl.No.	*Name*	*Place*	*State*
30.	Regional Research Laboratory	Jorhat	Assam
31.	Central Institute for Medicinal and Aromatic Plants (Research Centre at Lalkuan, Haldwani)	Lucknow	Uttar Pradesh
32.	Defence Field Research Laboratory	Pithoragarh	Uttaranchal
33.	Survey of India	Dehradun	Uttaranchal

Besides above listed institutions, there are other State and Central government organizations established in the Himalayan region. Thus, it is evident that we have institutional capabilities to address various scientific and technical aspects for development. The institutional culture is based on departments, divisions, sections/groups which is basically divisive approach but the need of the hour is to develop an integrated approach for problem-solving by developing strong non-institutional and multi-institutional linkages of partnership and team work. Non-government organizations (NGOs) were formed for effective transfer of technologies from government institutions to remote farmers but they have started indulging in creating new technologies and are becoming the critics of the government infrastructure rather than facilitators to both (i.e. institutions and farmers).

There is an urgent need to put all our knowledge (modern or traditional) into practice for sustainable development by sharing our strengths and weaknesses to address problem-solving in a constrained environment. Desirable and feasible actions for integrated approach to develop Himalayan region are discussed sector-wise (Anon, 1992). We have to ensure the interest of mountain communities and their environment as the prime perspective. This can be achieved by back up consortium of Government Departments, and technical institutions/ universities to provide necessary technical guidance and oversight to the programme of ecological security (Swaminathan, M.S., 1991).

8.3 POLICY ISSUES

Interplay of technologies, institutions and policies form the backbone of any pursuit for development.

Several acts for regulating grazing management and conservation of forests were passed from time to time. A historical act was also

legislated for managing torrents or flash-floods (Choes) in the Shiwalik hills of Punjab as early as 1900. Subsequently many laws were enacted in the agro-ecosystem for conserving land, water, vegetation, fishes etc. However, it has been difficult to enforce compliance of the government policies in the remote inaccessible, mostly common property or open access resources because of the following ground realities (Samra, J.S. et al, 19

Most of the policy instrumentalities were punitive in nature with disabling delivery.

- Many of the laws were alien to the traditional rights of the people and fulfillment of their basic and fundamental needs were not given due consideration.
- A transparent mechanism of sharing goods and services from the predominantly occurring common property or open-access resources was lacking. Local communities disowned the natural resources, considered them to be government property and over-exploited them even illicitly. The so-called protectors or regulators of these resources also became indifferent or ineffective for several considerations.
- Multiplicity of government departments/agencies and lack of proper coordination aggravated the conflicts about the sustainable use of many resources. For example, in some of the states, lakes and streams belong to forest department, village ponds to the local communities and they do not have meaningful joint programme with fisheries department for aquaculture.

There is a need for detailed studies for policy advocacy on issues such as legal status of the land, consolidation of land by mutual transfer within or between villages, management of common property resources, share of villages to the reserve forest produce and other government enterprises in management as well as benefits, credit policy etc. Further effective harmonization and integration of various policies pertaining to land use, water use, forest management, wild life preservation, road and infrastructure development, local institutions capacity building and watershed management are pivotal in timely accomplishment of the earmarked work and minimize departmental rivalry. Harmonization in the acts and bills of the departments is essential to enrich credit-worthiness of government

organizations. Thus, a major policy research should find a place in the agenda to develop new policy guidelines, which harmonize the activities of different departments and stimulate local people participation at all the stages of planned development.

The 73rd constitutional amendment (1992) of *Panchayat Raj* institutions (peoples' elected representatives) has attempted to empower the villagers. This federal model act has been adopted by the constituent states in India with several variations. Similarly, adoption of the centrally sponsored *Joint Forest Management Act* by different states has lost the basic philosophy in some of the cases. Involvement of women has been mandated in most of forward looking policy instruments. However, their participation in many instances and especially rural areas is mostly by proxy. The current guidelines of watershed management programme are alive to the needs of landless, weaker sections,. Women and skilled manpower. However, Panchayat Raj institutions are in the formative stage and have to go a long way in attaining maturity and responsiveness.

It is advisable to create village level voluntary institutions as alternative or competitive to the Panchayat Raj institutions. Some of the government departments, NGOs and international donors are experimenting with non-statutory organizations like watershed associations, self-help groups, village forest committees etc. Village level cooperatives and their federations may also be useful especially for accessing to distant markets by pooling their marketable products as well as inputs. The basic philosophy of these institutions should be to establish transparency, active participation, equity and contributions as a measure of ownership and conflict resolution.

ICIMOD has undertaken a series of country studies to explore land policy, land management and land degradation issues in the Hindukush Himalayan region (Blackie, P.M. and Sadeque, S.Z., 2000). Most of the policy documents are, paper exercises that are difficult to implement due to following reasons:

(i) Efforts should be made to avoid creating a centralized and coercive style of land policy.

(ii) Social justice, transparency, accountability and professional standards should be the main characteristics of good governance.

(iii) More paper work and less practice tendency should be avoided in favour of regenerative process on the ground.

(iv) Many and diverse initiatives are being taken all the time often by NGOs and community-based organizations.

Specific Policy Recommendations

Highest priority be given to those projects which do not deplete natural resources; strengthen the links between the research network and farmers; high value crops e.g. off-season vegetables, temperate and exotic vegetables and fruits, seed potato, and seeds for other vegetables will increase the farmers income; location-specific issues e.g. micro-watershed management, soil fertility etc. should be addressed by governments or NGOs; human training on natural resources management for social and community forestry; tourism as eco-tourism should be encouraged for increasing income and employment of local people; recognition and clear policy pronouncements of use right for various resources (surface water, pastures and forest) will benefit the mountain people and the renewed interest of global development community in institutions and rediscovery of the old social network concept for valid reasons suggests that policy planners concerned with poverty and good governance at least seek not to do harm to local institutions.

New strategic inputs suggested are :

- Increasing pressure on resources for both subsistence and commercial use, the waning of the legitimacy of the state, dwindling resources for policing, and a degree of demoralization of many forestry and agricultural support services are the main reasons. Decentralization and local participation, of course, are no panaceas, but to continue with centralized state-driven policies is not appropriate for the hills and is slowly becoming less and less practicable.
- The skills necessary for the transformation require continuous policy debate, new syllabuses, retraining and new terms of reference for all government personnel. The role of environmental referee and monitor for the ministries involved with agriculture and environment will become increasingly important.
- Current agreements between forestry services and local communities are also a form of a contract but are negotiated under conditions of extreme inequality and the latter are

virtually presented with a *'take it or leave it'* fait accompli. It may be possible to extend this notion of a more diverse and locally appropriate form of contract to include an economic, social and environmental plan with rolling targets and intermediate goals. This should be discussed and negotiated with the new emerging local institutions, and simple indicators of contract fulfillment agreed upon between all parties.

The principle of environmental entitlements or rights to natural capital, as an essential part of a livelihood, should be recognized officially. Perhaps , in the same way as an environmental impact statement should precede any policy decision regarding an infrastructural project, a social audit that forces policy-makers to confront the implications of their actions for livelihoods should likewise be introduced. At present, the rights are struggled for unofficially and ex-post, in terms of poaching, lawlessness or more organized and violent actions.

The entitlements are wider and more fundamental rights. Sometimes entitlements are abrogated in the higher national interest, compensation must be paid. The principle is sometimes conceded but seldom honoured. There are many cases in which governments have reneged on promises of compensations – to the same unfortunate set of displaced people at different times. This process continues, nullifying the intent and spirit of all policies and governance goals, and bewildering local people with a policy that makes promises but does not fulfill them. It is tempting to make connections between land policies that increase central control and deny livelihood right to locals, resulting in a large number of separatist political movements and conflicts, vitiating the whole environment and stopping all developmental activities.

EPILOGUE

Himalayan region is widely known as 'Land of Learning' as the Hindu scriptures – the Vedas, Upnishadas and Puranas were composed here from times immemorial. It has been the seat of a great spirituality, contemplation and meditation for sages, seers and poets, a place of devotion and penance for ascetics and a place of refuge for hermits, (Swami Sunderanand, 2001). Now a days, people treat them as important source of water, energy and biological diversity. These mountains are further regarded as reserves of key natural resources as minerals, forests, agricultural products and as places of recreation and tourism.

As a major ecosystem, representing the complex and interrelated ecology of our planet, mountain environments are essential to the survival of global ecosystem. Mountain ecosystems are, however, rapidly changing. They are susceptible to accelerated soil erosion, landslides and rapid loss of habitat and genetic resources. On the human side, there is widespread poverty among mountain inhabitants and loss of indigenous knowledge. As a result, the mountain areas are experiencing environmental degradation. Hence, the proper management of mountain resources and socio-economic development of the people deserves immediate action. Since the Rio Earth Summit in 1992, UNCED have been critical in successfully transmitting the message on the global importance of mountain area resources in terms of importance of freshwater supply, conservation of biological diversity, need for ecotourism and sensitivity to climate change. However, it is recognized that these initiatives to date have received positive but inadequate response from member countries There is still the challenge of promoting appropriate policy formulation, and of creating and implementing effective new programmes for the conservation, management and development of mountain areas. In this context, the International Mountain Year (IYM)- 2002, sponsored

by UN General Assembly is a big challenge and a great opportunity for convergence of efforts for regeneration of degraded Himalayan region in India.

Himalayan mountain system is the most important knot of the Euro Asian mountain system, spanning from the Pacific to the Atlantic Ocean. Himalayas, the highest and most majestic mountain range of the world, the cradle of Indian civilization, the weather-maker of Asia, the source of perennial rivers, have been of unparalleled significance of nature's precious treasure on Earth. It is the most sensitive and interactive land-ocean-atmospheric mountain system. The mountains are home to unique ecosystems, plants, animals and other organisms. The region is endowed with the highest ethnic and cultural diversity. Biodiversity in the region is being lost at all levels from genes in population within species to habitats and communities several plant and animal species are becoming extinct. Presently, Himalayas are suffering from serious ecological repercussions e.g. population increase of diverse cultures, reduction in forest cover, resulting in severe soil erosion, extensive runoff and land degradation. Sub-marginal lands are brought under cultivation resulting in poor soil and water conservation and silting up of drainage channels; shifting cultivation in North-East, dislodging staggering volume of soil; indiscriminate hunting threatening its fauna and unplanned mass tourism creating further ecological degradation. The landscapes of the Himalayas are adversely affected by impudent human intervention. Sections of population, who have been living in harmony with the environment for centuries are being marginalized due to pursuit of power and profit by those who hold reins of decision-making from within the country and also at the global level. The mountain system has become a battle-ground between conservationists and commercial interests. Many are convinced that the Himalayan problems can neither be solved by adopting megabuch,high-tech approach nor by doomsayers' dreams that there is no longer any hope at all for the environment. Only a mixture of deep concern and cautious optimism is needed. Avarice and indifference should not be allowed to destroy the natural heritage of tremendous importance to humankind.

Despite general degradation of the environment, the region encompasses several 'resource rich spots'. The region does enjoy monopoly in the production of virus-free potatoes, tubers, temperate fruits particularly apples and several high value cultivated as well as

wild crops which provide scope for designing alternatives or complement to traditional agriculture as an instrument for development in the region. A recent regional comparative analysis of the state of mountain agriculture in the region (Tulachan, P.M., 2001) shows that the production of food grains has not declined as much as is often thought. In some cases, the production has actually increased as a result of increased productivity due to increased access to modern inputs e.g. quality seeds, fertilizer and irrigation. Per capita availability of food may decline due to increase in population. The study also revealed that there is increasing diversification and introduction of horticultural and cash crops. Mountain people can specialize more in high value crops (HVCs) such as fruits, vegetables, flowers and medicinal plants and lowland farmers in cereal crops. This may lead to an effective trade exchange mechanism between the highlanders and lowlanders and also help pollution control from use of chemicals for increased production.

The key challenge facing the policy makers, planners, researchers and field workers is how to address the emerging environmental and socio-economic issues in order to ensure that the production of HVCs can be sustained on a long term basis. Globalization might affect the harnessing the mountain niches in terms of HVCs having comparative agroecological and agroclimatological advantages. The implications of linkages between the mountains and the lowlands in the context of globalization of markets, may point to the adverse terms of trade against uplands and the one-way drain of resources without compensatory mechanisms. The penetration of markets into mountain areas may accelerate this process unless the capacities of mountain regions and their people are raised to take advantage of emerging opportunities in the global markets and compensatory mechanisms are developed for the resource flows that cannot be easily taken care by price and market mechanism.

The contents of the publication emphasize the need for multidisciplinary approach for the study of the atmospheric geospheric & hydrologic and biospheric aspects so that the natural hazards could be minimized and poor socio-economic conditions of mountain inhabitants are alleviated. An integrated approach is needed for conserving, upgrading and using the natural resource base of land, water, plant, animal and human resources. In addition, promoting alternative livelihood opportunities, particularly through development

of employment scheme that increase the productive base, will have a significant role in improving the standard of living among the rural population living in the mountain ecosystem. The potential for interdisciplinary cooperation for the development of synergies between different disciplines and for the spatial and temporal co-ordination of data bases has to be harnessed. Development of co-operative, participative and flexible policies for resource management at local, regional and national levels are needed to deal with the changing environment. This will also be helpful in dealing with the climate change issues in different mountain regions.

Futures of mountain communities and regions must be addressed holistically and strategically. This will require a move beyond current and well-known approaches which have tended to be rather myopic, sectoral and geographically limited. It also implies the involvement of not only professional 'planners' and policy makers, but also tourism industry and the diverse stakeholders involved in mountain communities from the earliest stages of issue definition through the implementation and monitoring of policies (Price, M.F. et al ,1997) .

Let us recall that the scholars are increasingly inclined to believe that the foothills of Himalayan ranges and their surrounding peaks make up one of the cradles of humankind. As the Himalayan mountain system produced the stimulus for human origin as a biological entity, the multiple challenges to the adaptive processes posed by the contemporary problems related to the region, will stimulate humanistic impulses to be expressed in the most prudent and creative manner. Our hominid ancestors started a journey at the foothills of the Himalaya, let us try to reach the peak of humanistic self-realisation through mutual cooperation and non-stop arduous efforts for the regeneration of these mountains.

I. DAZZLING HIMALAYAN MOUNTAIN PEAKS

(a) Kailash (6740m)

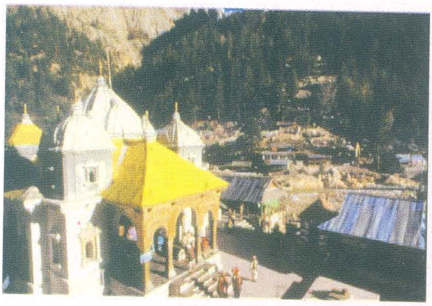
(b) Kanchanjunga (8598m)

(c) Nandadevi (7817m)

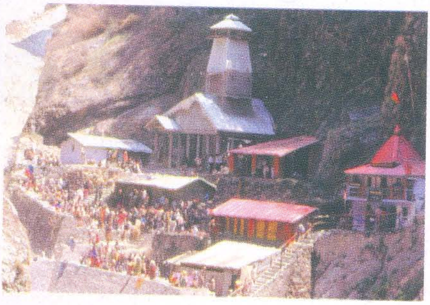
Shivling (6543m)

(Photo by Ashok Dilwali)

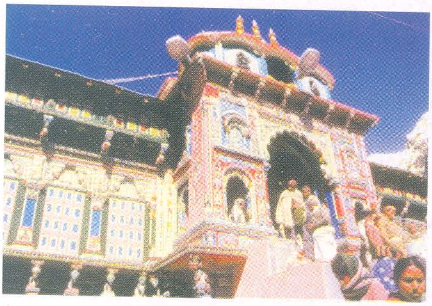
II. IMPORTANT PLACES OF PILGRIMAGE



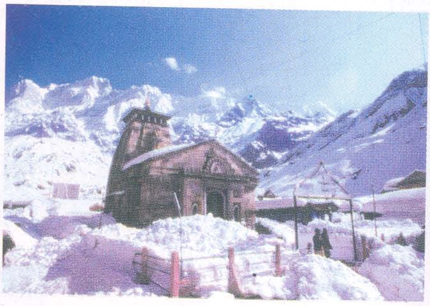
(a) Ganga temple at Gangotri



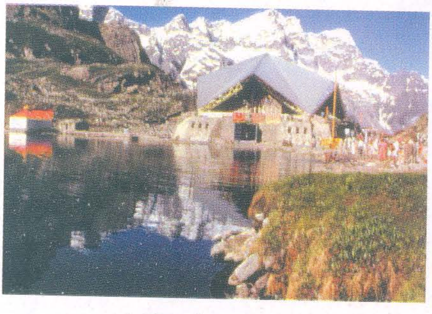
(b) Yamuna temple at Yamunotri



(c) Lord Badri Vishal at Badrinath



(d) Lord Shiva temple at Kedarnath



(e) Hemkund Saheb

(a), (b) are located in Uttarkashi district while (c) (d) and (e) are located in Chamoli district of Uttaranchal.

(Photo by Ashok Dilwali)

(III) VERDANT VALLEYS

(a) Rice fields in Gangotri region

(b) Agro forestry practised in flood plains of mountain streams

(c) Terraced Agriculture- A variety of crops

(Photo by Directorate of Extension, MOA)

(IV) PERPETUAL SNOWS

(i) Permanent snows around Satopanth (7075m), Kumaun Himalayas
(Photo : IMF Mt Kamet expedition, 1999)

(ii) Deep snow condition around Mana Massif (6795m)
(Photo : IMF expedition 1999)

(iii) More than a meter snow fell in the first week of october 1971 at Gaumukh during Inter-Departmental Glacier expedition
(Photo by the Author)

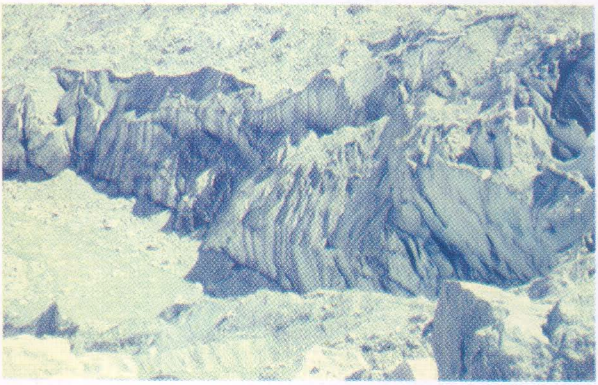
(V) RETREATING GLACIERS

A Distant view of Gaumukh-Snout of Gangotri Glacier, 1971

(Photo by the Author)

(ii) Gaumukh in 1999, Gangotri Glacier is receding at an average rate of ~30m/yr

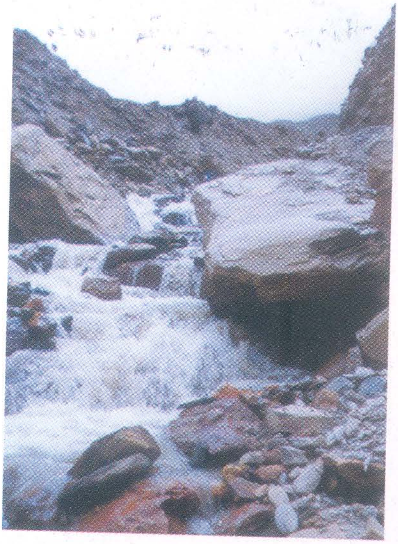
(Photo by NIH, Roorkee)



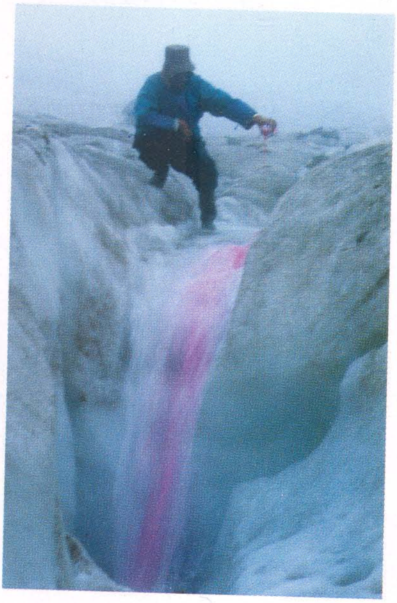
Exposed Surfaces of Crevasses with water body and Debris on Gangotri Glacier

(Photo by the Author)

(VI) RUSHING STREAMS



(i) Rapid Glacier-fed Stream at about 4000m in Nanda Devi Bioreserve.



(ii) Dye tracer experiments for flow studies in a moulin (roughly cylinderical and nearly vertical hole upto 30m on a gracier surface

(iii) Water Fall from Arunachal Pradesh

Photos (i) & (ii) by JNU Glacier Research Group and (iii) by Ashok Dilwali

(VII) SHINING LAKES

(i) Nainital Lake (Uttaranchal) in January Month

(ii) Pangong Lake in Ladakh (J&K)

(Photos by Ashok Dilwali)

(VIII) BAFFLING BIODIVERSITY

(a) Food Grain Crops

↑(i) Wheat crop

↑(ii) Rice crop

← (iii) Maize crop

↑(iv) Jowar crop

↑(v) Soya Bean Crop

(vi) Gram crop →

(Photos : Directorate of Extension, MoA)

(b) Oilseed Crops

(i) Mustard Crop

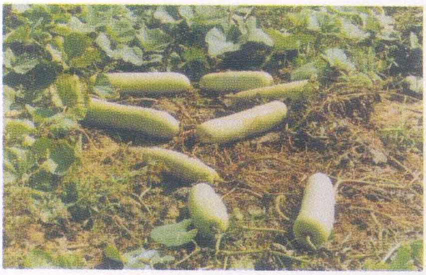
(ii) Sun Flower Crop

(iii) Till Crop

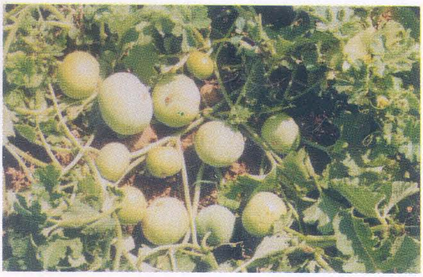
(iv) Cotton Crop

(Photos by directorate of Extention. MoA)

(c) Vegetable Crops



(i) Bottle Gourd
(Lauki-Lagenarea Siceraria)



(ii) Round Gourd (Tinda-Citrullus)

(iii) Ridge Gourd
(Torai-Luffa acutangula)

(iv) Brinjal (Baigan-
Solanium-ruttomfena)

(v) Tomato (Timatar-
Lycoperiseon esculentum)

(vi) Radish
(Muli-Raphans Sativua)

(Photos by directorate of Extention. MoA)

(vii) Cabbage (Band or Pata gobhi-
Brassica oleraciavarcapitata)

(viii) Cauli flower (Phool gobhi-
Brassica oleraceavarcapitata)

(ix) Peas (Matar-Pisum Sativum)

(x) Lady Finger
(Bhindi-Abelmoschus esculantum)

(xi) Button Mushroom

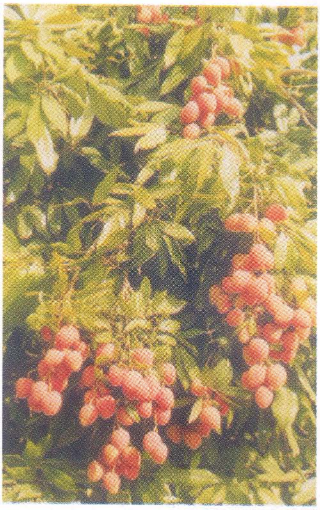
(xii) Chillies
(Mirch-Capsicum frutescens)

(Photos by Directorate of Extention, MOA)

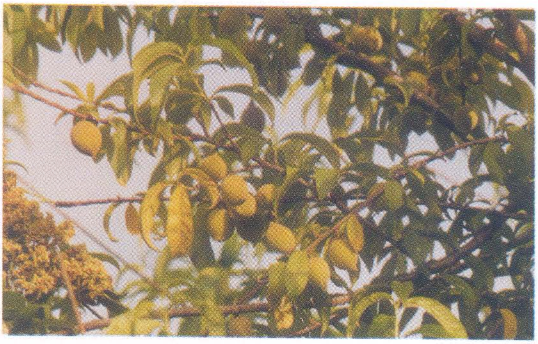
(d) Fruit Crops

↑ (i) Apples

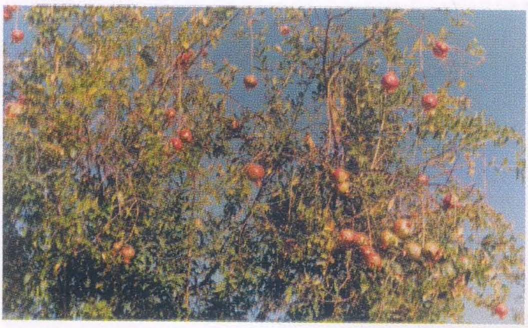
↑ (ii) Oranges



↑ (iii) Lichi

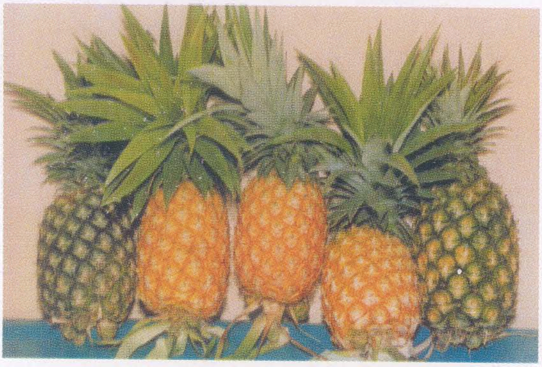


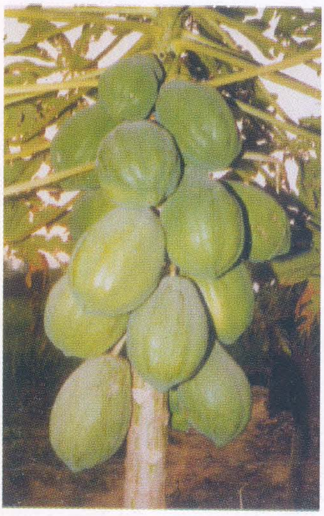
↑ (iv) Peaches (Aarhu)



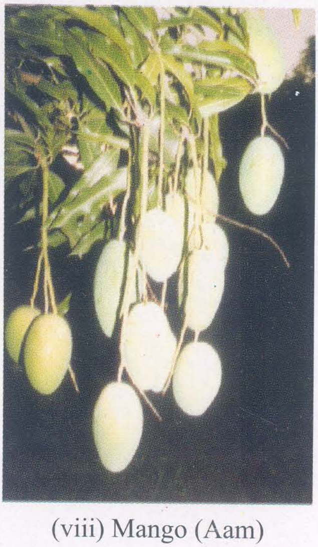
(v) Pomegranate (Anaar)

(vi) Pine apple (Ananas)





(vii) Papaya (Papita)



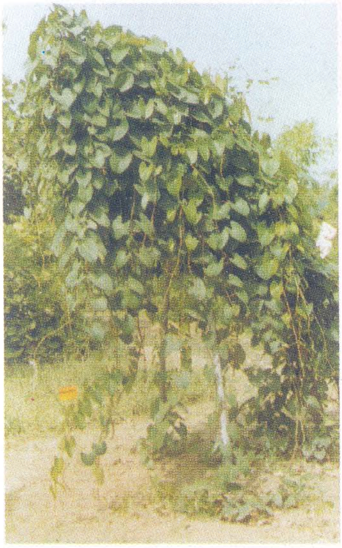
(viii) Mango (Aam)

(Photos by directorate of Extension. MOA)

(e) Medicinal Crops

(i) Pendilanth

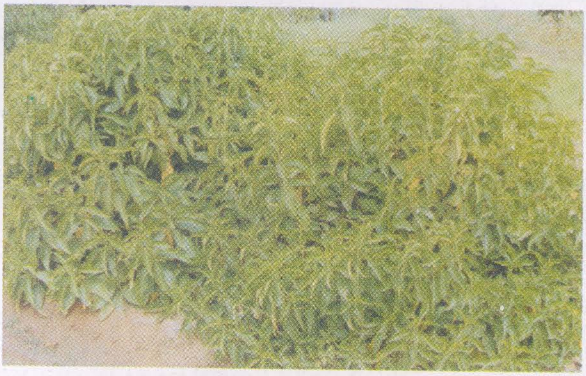
(ii) Termaric



(iii) Discorea Bulbifera

(iv) Nagbola

(i) Lemon Grass



(ii) Rusa

(iii) Kevda

(iv) Kala Bans

(Photos by Directorate of Extention, MOA)

(f) Flowers

(i) A

(i) B

(i) Colourful roses from western Himalayas

(ii) Brahma Kamal- Saussurea obvaltata- a highly endangered alpine plant of western Himalya

(Photos from GBPIHED)

(iii) Lillium - A high value exportable flowers

[(i) and (iii) Photos from IARI]

← (iv) A

(iv) B →

← (iv) Gladiolas from →
eastern himalyas

Photos from IARI

←

(v) Rhododentrum in the forest week of April at Pithuragrah

(vi) Orchids from Sikkim

(vii) Wild flowers from higher Himalayas near Tibet border

(Photos by Ashok Dilwali)

(g) Fauna

(i) Snow leopard at Darjeeling

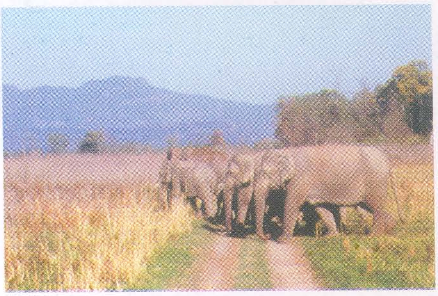
(ii) Cheetal at Chulka

(iii) Yaks in Sikkim

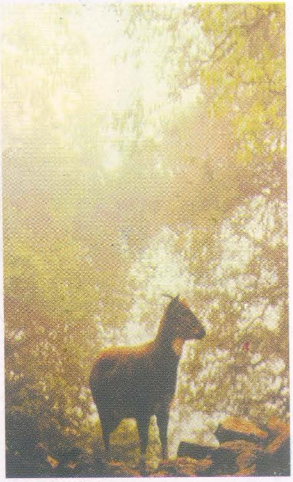
(iv) Wild asses near Chusul, Ladakh

(Photo by Ashok Dilwali)

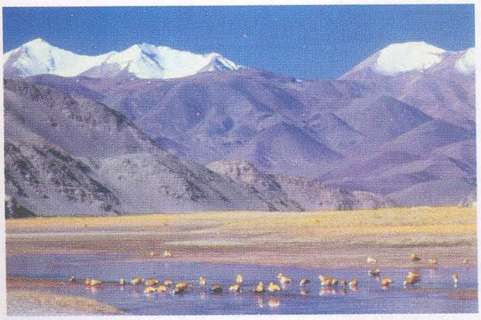
(v) Sheep near Martali in Pithoragarh, Uttaranchal



(vi) Elephants at Corbett National Park, Uttaranchal



(vii) Barking Deer (Muntiacus muntjac)
in Himalayan Nature Park, Kufri, Himachal Pradesh



(viii) Brahamic birds in October
at Nijoma Village, Ladhakh

(Photos by Ashok Dilwali)

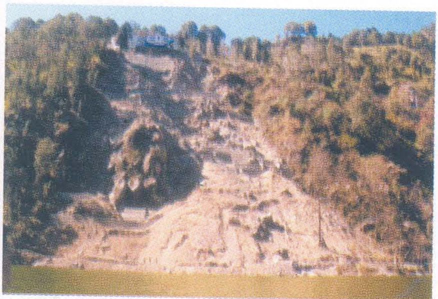
IX DEVASTATING HAZARDS

Earthquake

Forest fire

Landslides

(i) Khanera landslide blocking the Yumuna river channel due to the cloud burst in September 2001

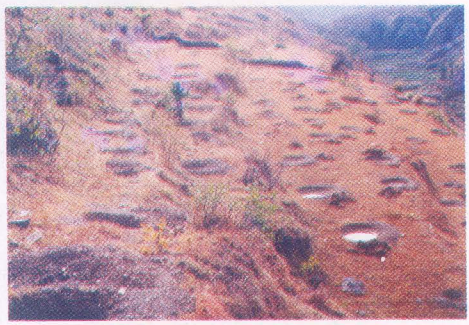


(ii) Landslide due to restricted drainage resulting in slope failure above the Nainital lake in 1999.

(X) REJUVENATION AND REGENERATION EFFORTS

(i) Chaal : The Traditional Recharge Pit

(ii) Planting on Community Lands

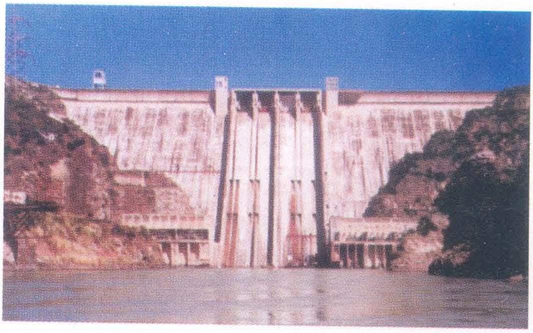


(iii) Denuded hilly catchment area and muddy water in reservoir in the year of inception of Sukhomajri project

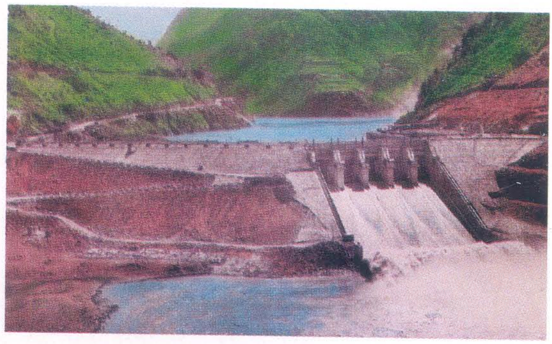
(Photo S.P.Mittal)

(iv) Denuded hilly catchment area and muddy water in reservoir in the year of inception of Sukhomajri project and in after protection

(Photo S.P.Mittal)



(v) Bhakra Dam

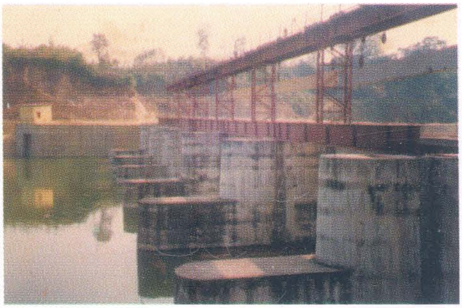


(vi) Pandoh Dam (H.P)

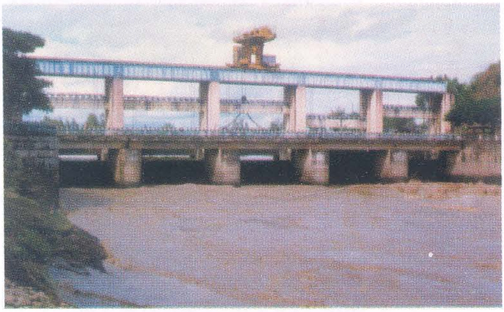
(vii) Steel Bridge across river Ravi
540 MW Chamera HE-project (H.P)

(viii) Teesta Barrage Project
(W.Bengal)

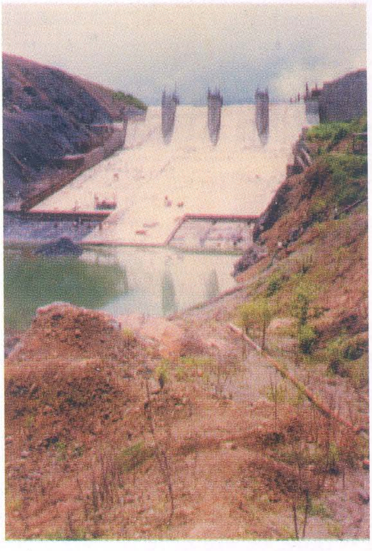
(Photos from Ministery of Water Resource)



↑ (ix) Manu Barrage-
medium irrigation project (Tripura)



↑ (x) Loktak Hydroelectric project (Manipur)



↑ (xi) Khuga Multipurpose
Major irrigation project (Manipur)

(Photos from Ministery of Water Resource)

(XI) SOME SOCIO CULTURAL ASPECTS

(i) Traditional Band from Sikkim (Photo from Sikkim House)

(ii) Bamboo Basket Making in Arunachal Pradesh

(iii) Dances of Tribal Arunachal Pradesh

(Photos by Ashok Dilwali)

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AN ODE TO HIMALAYAS 1986*

HIMALAYAS – You are the abode of Gods
Our northern great wall
You are our guide, our guard.

HIMALAYAS – You are home of snow
And of Glaciers
From where thousands of rivers flow.

You are sacred sublime
You are closer to Heaven,
You are home of Badrinath Kedarnath,
Vaishnodevi Amarnath where millions climb.

Your peaks Pir Panjal, Nandadevi, Anna Purna
Kanchanchunga, Kedarnath, Gangotri,
Also Kailash Manasarovar All
Speak of your majesty, glory.

You are Grand, Majestic, Serene, Inspiring
View from Almora Forest Guest House
In early morning sun or from Kausani and
Hundred other sites.

You are giver of life, trees, springs
Flowers medicinal plants and now
You are instead beginning of floods misery
But mighty Himalayas – you are bleeding crumbling
Too much pressure – too many demands put on you.

People worship and adore you in
One breath and hurt you, injure you in next one.
Why this hypocricy, this indifference?
Can this be reversed or is it too late?
It is late in my humble views
But not too late.

We all must work together young and old
Instead worshipping you with empty words
Take direct steps positive and bold
Plant more trees
Nurse more trees
Cut less trees

Burn less trees.
Promote integrated use of Himalayan Resources
Revive the springs
Life blood of Himalayas
Remove poverty from your sacred land
A call to the people the Govt.
To join in these efforts.

We pledge to save our sacred Himalayas
Sources of our Mother Ganga
And benefactor of our fertile now
Sick plains of Indo-Gangetic Brahmaputra.

We promise we all will work together
To bring you to the forested glory
Majesty Greenness Sacredness.

*Source: Dewan, M.L. and Skolimowski

HIMALAYA - SOME DESCRIPTIONS

A few notable descriptions of Himalaya ,as appealed to the author are listed as follows:

- 'Himavat' become 'Himalaya' later
- **'Himalaya' – literally means a storehouse of snow and ice and is known as the abode of eternal snow where Gods live.**
- It is known as 'Giriraj' or 'Nagadhiraj' i.e.the king of mountains.
- Poets have called it 'Sartaj' of India. i.e. head crown of India.
- As it contains 530 peaks above 6000 m and 14 mountain peaks over 8000 m and 100's over 7000 m, it is also referred to as the 'Roof of the World'.
- Americans called it as a 'Third pole' as its' snow and ice fields rival those of polar regions (Arctic and Antarctic).
- The mountain system still preserves many unspoiled and unpolluted spots as the man could not approach them and therefore it is the greatest storehouse of natural secrets in the world, offering challenges to explorers.
- The mountain system holds an indescribable charm, inspiration and spiritual significance to the millions.
- Many believe that it is impossible to describe the mysticism and religious aura that surrounds these mountains.
- Great scholars, sages and poets tried to describe their sheer majesty and charm but could never capture in words, the eternal truth which abides in them.
- According to Bhagwat Geeta, the concept of bulk, immobility and steadfastness of our earth reached its limit in one word – 'The Himalaya' – the world's mightiest mountain.
- Poet Kalidasa, in his famous poem, Kumarasambhava called them 'Manadanda', literally the measuring rod of the Earth.
- Himalayan Dilemma – Selected denudation rates range from 0.5 to 20 mm per year. Despite the wide range, these are very high as compared to the denudation rates elsewhere in the world and suggest a very dynamic environment (tectonic uplift 4-5 mm per year) and high seismic activity.- Ives and Messerli.
- The Himalayan arc forms an ecological Gibralter, whose fate looms large over the well-being of hundreds of millions - Eric Eckholm.

G B PANT MEMORIAL LECTURES - SOME SALIENT POINTS*

The following lectures have been delivered by the distinguished personalities from 1991 onwards:

S.No	*Distiguished Speaker*	*Topic*	*Date*
I	**Dr. M.S. Swaminathan** Director, Centre for Rural Development, Chennai.	Ecological Security of the Himalayas	14-9-91
II	**Dr. T.N. Khoshoo** Jawahar Lal Nehru Fellow Plant	Diversity in the Himalayas : Conservation and Utilization	14-9-92
III	**Mr. V. Rajagopalan** Vice President The World Bank, Chairman, Consultative Group on International Agricultural Research (CGIAR)	Development of India's Himalayan Region	
IV	**Dr. U.R.Rao** Member, Space Commission, Bangalore	Space for Sustainable Development with special emphasis on Himalayan Region	25-10-94
V	**Dr. S.Z. Qasim** Member, Planning Commission New Delhi	Some Major Socio Economic and Environmental Issues of the Himalayan Region	14-9-95
VI	**Dr. S.K. Joshi** Vikram Sarabhai Professor	Some Issues related to Sustainable Development of the Himalayan Region	2-10-96
VII	**Dr. K. S. Valdiya** Bhatnagar Research Professor, Jawaharlal Nehru Centre for Advanced Scientific Research Bangalore	Developing a Paradise in Peril	18-12-97

S.No	Distiguished Speaker	Topic	Date
VIII	**Dr. Vinod K. Gaur** Distinghished Professor Indian Insitute of Astrophysics, Bangalore	Mitigating Disaster in the Himalayas – a Basic Agenda for Development	30-10-98
IX	**Dr. H.Y. Mohan Ram** INSA Senior Scientist Department of Environmental Biology University of Delhi	Plant Resources of the Indian Himalayan Region : Some Points for Action	20-2-2000

Some salient remarks have been extracted to highlight the relevance and importance of Himalayan Environment and its' Agrosystems:

I. (Dr. M.S. Swaminathan)

- The ecological security of the Himalayas is not only vital for the welfare of the hill people and their children but also for the food security of India. The future of agriculture in the Indo-Gangetic plains, a major food basket region of India and of the world, will be determined by what we do or do not do in the Himalayas today.
- Many of the ecological and human problems of today in the Himalayas owe their origin to segmented thinking and action. Some of the recent examples are :
  - Construction of road and intensification of deforestation
  - The rapid growth of apple industry
  - The direct extraction of medicinal plants
  - The neglect of traditional crops – 'health food'
  - The promotion of sheep husbandry
  - The rapid increase in population in recent decades
  - The growth of tourism
  - The construction of dams and barrages
  - The shifting cultivation and invasion of cleared lands by non-edible weeds (Eupatoruni, Mekenia and Lantana)
- The Himalayas is rich not only in biological diversity but also in cultural diversity. In spite of such diversity, there is unity in the major problems facing he people of Himalayas, namely poverty, population growth and environmental degradation. The solutions to such problems are however location specific. They have to be developed through participatory research with local women and men. GBPIHED should spearhead the concept "Think Himalayan but analyse and act locally".

Priorities

Participatory Research

Fostering of participatory research designed to promote a new paradigm of development based on the integration of the principles of ecological sustainability, economic efficiency and social equity. The maximum impact of the distribution of land, water and biomass resources falls on women who play the major role in the collection of fuel, fodder and water. A major aim of the participatory research programmes should be the standardization of location specific methods of improving biological productivity and quality of life. There is need for a land and water use strategy for each compact agroecological zone with a view to promoting three end uses viz. (i) Conservation areas (ii) Restoration areas (employment guarantee) and (iii) Sustainable intensification.

In addition there will be need for anticipatory research in areas such as the following :

(a) Renewable Energy Sources
(b) Consumer Preferences
(c) Packaging and Marketing
(d) Adoption of Biotechnology
(e) Computer Simulation

A back-up consortium of Govt. Departments, and technical institutions/ universities should be formed to provide the necessary technical guidance and oversight the programme.

II. Dr. T.N. Khoshoo

An agro-ecosystem is essentially a man-made ecosystem which is geared to meeting basic human needs of food, fodder, fuel, fertilizer, fibre, timber, medicinal and commodity crops and also giving some economic returns. The underlying purpose is the production of these goods and services on a sustainable basis. Such an ecological approach to agricultural production is based on the concept of creating productive and sustainable systems with resource-conservation and risk-reducing aspects of traditional farming methods appropriately blended with modern advances in biology, particularly biotechnology. Equally important are socio-economic and other aspects like tenure, farm size, pricing policy, local markets and less dependence on sophisticated farm implements and chemicals. The system has to maintain optimum sustainable production of food and income over long periods.

The evolution of agro-ecosystems has been necessitated by escalating population from a hunter-gatherer system, humankind became sedentary

and got attached to a particular locality. Thus, in essence the evolution of agro-eco-system became inevitable on account of a major change from food gathering to food-producing. During this process, human being has eliminated all the species except those on which he depended for his food, fodder, fuel, fibre, fertilizer, medicare and some vocations. Over the years, this change has affected the hydrological and geo-chemical cycles. All in all agro-ecosystems are there to stay and these along with shifting cultivation have to be refined and made sustainable by scientific and technological inputs taking into account the indigenous knowledge. This is particular true for Himalayan agro-ecosystems - The role of plant genetic resources in the development of hill agriculture is already recognized. It needs to be widened to encompass all the relevant biodiversity for diversification and intensification of biomass production. Together with some socio-economic measures, it holds the key to the health and wealth of Himalaya and its people. It is also critical input to *antodaya* (welfare of the weakest) and *Sarvodaya* (welfare of all).

III. Shri V. Rajagopalan

Land and water degradation, the reduction of biodiversity, environmental pollution, farm productivity and sustainability are affected by decisions taken at farm, community, institutional and policy levels. However, these same levels also offer leverage points for solutions involving interconnected decisions. The interlocking nature of the problems faced, also requires that these be more complementarity and less duplication among research scientists, more effective linkages between the global and regional research, and more effective transnational collaborative.

IV. Dr. U.R. Rao

In spite of the green revolution, the agricultural productivity in India is one of the lowest being about 1.6 t/ha as against world's average of 2.6 t/ha and world's best of 5 t/ha. The average yield of rice in India is just above 1.7 t/ha as against 5.0 t/ha in California.

V. Dr. S.Z. Qasim

There is no denying the fact that in the Himalayan region, the socio-economic development has not been harmonious with the ecology of the mountains.

VI. Dr. S.K. Joshi

In the Himalayan region, there is need to educate a cadre of development engineers.

For development programmes to be successful, there is need to promote alliance between educational institutions, research laboratories, government departments and non-government organisations. Such alliances will be effective in dissemination of knowledge and technology relevant to various projects.

VII. Dr. K.S. Valdiya

Aspects which deserve paramount consideration by the planners :-

- Quickened Earth Processes and Safety from Natural Hazards
- Water Conservation and Spring Sanctuaries
- Conservation Forestry and Tree Cropping
- Women: The Natural Managers of Resources
- Taming Rivers without Bad Impacts
- Utilization of Wealth Stored in Rocks
- Road Networks

We have to develop and offer working models of ecological and socio-economic development – of hazard zoning and risk preparedness exercises; of spring sanctuaries and water harvesting devices; of tree-cropping farms and ecologically sound pastures; of micro-hydel projects; of geothermal energy plants; of small scientific paving stone or slab quarries etc.

VIII. Dr. V.K. Gaur

The ongoing revolution in Information Technology and wide area connectivity combined with considerable expertise in sensor technologies available in the country, open up exciting workable opportunities for developing such systems even in a low technology environment such as the Himalaya (CSIO, Chandigarh).

There are great opportunities of our age waiting to be grasped and harnessed, to realize a great dream of banishing the spectre of disasters from the Himalaya and turning the mountain fastness into dreamland that would continue to chasten and exalt our sprits.

IX. Dr. H.Y. Mohan Ram

Decimation of forests to meet the greed of the rich far above the needs of the poor, have seriously shrunk the national areas which support microbial, plant and animal wealth and from where all native agricultural crops have been selected. Biologists have emphasized that the long-term maintenance of the health of an ecosystem is the ultimate aim of sustainable development.

Source: G.B.Pant Institute of Himalayan Environment and Development, Kosi, Almora-243643

HIMALAYAN EXPERIMENT (HIMEX) TO IMPROVE DATA BASE FOR HIMALAYAN REGION.*

A Himalayan Experiment (HIMEX), along the lines of ALPEX, has been proposed with the following scientific objectives:

- To improve the understanding of mountain waves and mountain roughness representation in large scale atmospheric models.
- To appreciate spatial variability in meteorological parameterisation at sub-grid scales for GCMs.
- To develop mesoscale and regional numerical models with detailed parameterization of land-surface processes for local specific operational weather forecasts.
- To study the air flow, mass and moisture fields over and around the mountain ranges under various synoptic conditions.
- To study precipitation patterns and orographic contributions at different altitude ranges during summer and winter seasons.
- To determine the role of diabatic heating associated with lee cyclogenesis over the Bay of Bengal for cyclone forecasting.
- To understand dynamic and physical processes associated with storm activity (thunder storms, Nor' westers) better.
- To study the modifying effect of radiative cooling on weather systems over the cold north-west region.
- To study the modifying effect of diabatic heating on weather systems over a warm southeast region.
- To help establish a data base for the cold Himalayan region for collecting storing and dissemination information on seasonal/ perennial snow and ice processes, interaction with the physical environment and effect on climate and its change.

The project (HIMEX) will need high level national, regional and international coordination for its implementation.

* Source : Bahadur, J (1995)

INTERNATIONAL CENTRE FOR INTEGRATED MOUNTAIN DEVELOPMENT (ICIMOD)*

OBJECTIVES AND FUNCTIONS

ICIMOD will play a supplementary and reinforcing role, rather than a competitive or parallel one, in supporting and furthering the effectiveness of existing institutions and national, bilateral and international bodies already operating in the region. In pursuing its chief objective to promote integrated mountain development in the Hindukush Himalayas – the major functions of the Centre are described as follows :

- Clearing-house for multi-disciplinary documentation and information dissemination.
- Coordinator and provider of consultative services in scientific and technical matters related to development, planning and actions.
- ICIMODs research functions fall under the categories; Synthesizing, evaluating, and translating research data in order to facilitate its application to integrated development.
- Identifying gaps in knowledge in he Hindu-Kush-Himalayas.
- Stimulation and coordination of research needed to fill the gaps in knowledge.

*Source:International Centre for Integrated Mountain Development (ICIMOD), 1984

Ev-K^2-CNR PROJECT*

A project of CNR (the Italian National Research Council) in cooperation and agreement with RONAST (The Royal Nepal Academy of Science and Technology).

"Laboratory of studies and research at high altitude"

The Pyramid has been installed at 5050 m altitude in the Sagarmatha (the Nepalese name of Mt. Everest) National Park, close to a glacial lake above the mountain pasture of Lobuche. The place is 100 km far away from the nearest village connected to Kathmandu by a carriage road, and the further journey requires a trekking of about ten stages.The research topics in various scientific fields are outlined:

- Earth Science (Remote Sensing, Geodynamics, Geophysics, Geodesy, Geology, Glaciology)
- Medical Science (Physiology of the Circulatory System, Endocrinology–Cardiology,Cardiology-Pneumology, Neurophysiology, Respiratory Physiology, Tisiology)
- Biological Science (Ornithology, Agronomy,Botany)
- Environment Science (Global Circulation of Pollutants, Physics of the Atmosphere, Hygiene)
- Human Science (Ethnography)

* Source: Scientific and Technologic Research at High Altitude and Cold Regions,1992, CNR, Milano

2002 AS THE INTERNATIONAL YEAR OF MOUNTAINS (IYM)*

The International Year of Mountains promotes the conservation and sustainable development of mountain regions, thereby ensuring the well-being of mountain and lowland communities.

Thematic concept

Sustainable mountain development includes a wide range of topics, calling for interdisciplinary, integrated approaches. Priorities cannot be the same in diffeent mountain regions of the world. The concept for IYM preparation and implementation should reflect this diversity, and be flexible and adaptive. The concept for IYM preparation and implementation should be flexible and should reflect the diversity of mountain ecosystems.

- The **thematic clusters** list the variety of mountain-related issues which might be considered high priority and addressed in one way or the other in IYM implementation.
- The **clusters of methods and means for implementation** indicate the ways in which the selected thematic elements might be designed and implemented. These clusters were defined at a brainstorming session during the fifth meeting of the Inter-Agency Group on Mountains in March 1999.
- The **geographical clusters** address the level (global, regional, national and local) at which initiatives will be carried out.

Mountains clearly represent more than just areas of high peaks, tourist attractions or natural hazards; mountains are the water towers of the world, and areas of great biological diversity hosting rich forests and unique land-use systems. Due to their remoteness, people living in mountain areas have developed rich cultural heritage but often suffer from economic constraints and poverty. All these characteristics make mountain areas extremely sensitive to mismanagement of their natural resources and external influences on local economies and cultural heritage, as well as to the effects of global change. But despite their fragility and harsh environments, mountain ecosystems can also be resilient and offer considerable opportunities in support of sustainable development.

UN General Assembly's decision to observe an IYM in 2002 constitutes a milestone in the process of raising awareness concerning mountain areas, their global importance and the fragility of their resources. It offers an

outstanding opportunity to improve livelihood opportunities for mountain inhabitants, to promote sustainable use and conservation of resources, and to increase knowledge on mountain ecosystems. It is important not to squander this opportunity, but to ensure that all the events and activities organized in IYM observance lay the foundation for ongoing action towards the conservation, sound management and sustainable development of mountain resources for the benefit of mountain communities and indeed the whole of humanity.

*Source: International Year of Mountains-Concept Paper. United Nations,FAO,2000.

GLOBAL CHANGE AND MOUNTAIN REGIONS: THE MOUNTAIN RESEARCH INITIATIVE (MRI)*

In order to address the consequences of global change in mountain regions, an initiative for collaborative research on global change and mountain regions –the Mountain Research Initiative (MRI) – was developed and officially launched in July, 2001 with the opening of the Coordination Office in Bern. The MRI has been formally endorsed by the International Human Dimensions Programme on Global Environmental Change (IHDP), the Global Terrestrial Observing System (GTOS) and four core projects of IGBP, i.e. GCTE, BAHC, PAGES, and LUCC. The ultimate objectives of the initiative are:

(a) to develop a strategy for detecting signals of global environmental change in mountain environments;
(b) to define the consequences of global environmental change for mountain regions as well as lowland systems dependent on mountain resources; and
(c) to make proposals towards sustainable land, water and resource management for mountain regions at local to regional scales.

To achieve the above objectives, the research under the MRI is structured around four Activities, each of which is divided into a small number of specific tasks.

Activity 1: Long-term monitoring and analysis of indicators of environmental change in mountain regions.

This element of the Initiative will focus on mountain specific indicators of environmental change which are sensitive to changes in climate, atmospheric chemistry, radiation, and land use/land cover. A set of four mountain-specific indicator groups is considered :

(1.1) Cryospheric indicators related to snow conditions, glaciers, permafrost and solifluction processes;
(1.2) Terrestrial ecosystems, particularly mountain plant communities and soils;
(1.3) Freshwater ecosystems, in particular high mountain streams and lakes; and
(1.4) Watershed hydrology, i.e. water balance components of high mountain watersheds/headwater basins.

Activity 2: Integrated model-based studies of environmental change in different mountain regions

To achieve the overall goals of the Initiative, it is necessary to develop a

framework that permits the analysis and prediction of hydrological and ecological characteristics and their linkages with land use and climate at various spatial and temporal scales. Accordingly, this activity is organized around the following:

(1.1) Development of coupled ecological, hydrological and land use models for the simulation of land cover and land surface processes in complex mountain landscapes;

(1.2) Development of regional scale atmospheric models for mountain regions;

(1.3) Integrated analysis of environmental change in mountain regions by means of fully coupled land-atmosphere models or by qualitative assessments; and

(1.4) Regional scale mountain land experiment to support the development, application and validation of the above models.

Activity 3: Process studies along altitudinal gradients and in associated headwater basins

Ecological and hydrological field studies and experiments along altitudinal gradients and at sensitive sites can provide invaluable data on potential responses of mountain ecosystems to anthropogenically induced environmental change. Research themes to be addressed within this Activity include :

(1.1) Development of indicators of mountain ecosystem response to environmental forcing factors to facilitate process-related interpretation of historical and paleo-records;

(1.2) Assessment of runoff generation and flowpath dynamics on steep hillslopes and in headwater catchments; and

(1.3) The relationship between diversity and ecosystem function, taking advantage of the strong changes of diversity along altitudinal gradients.

Activity 4: Sustainable land use and natural resources management

The overall objective of this Initiative is to evaluate and enhance sustainable land, water, and resource management strategies for mountain regions. Three priority areas are suggested for assessment:

(1.1) Changes in forest resources, with potential implications for agriculture, rates of erosion and magnitude of floods, and biodiversity;

(1.2) Intensification and/or extensification of agriculture (including grazing), with potential implications for food security, rates of erosion and magnitude of floods, and biodiversity, and

(1.3) Changes in water resources due to factors such as changing agricultural practices, increasing temporary or permanent population, and/or increasing energy generation, with implications for downstream water supply, energy availability, flooding, and sediment transfer.

The MRI implementation Plan has been published as number 49 in the Global Change Report Series and can be ordered free of charge either from the !GBP sedretariat in Stockholm or the MRI Coordination Office in Bern or downloaded from

http://www.igbp.kva.se/cgi-bin/php/frameset.php

Web links

Mountain Research Initiative (MRI): *www.mri.unibe.ch.*

Biospheric Aspects of the Hydrological Cycle (BAHC): *www.pik-posdam.de/~ahc/*

Global Cange andTerrestrial Ecosystems (GCTE): www.gcte.org

The Global Observation Research Initiative in Alpine Environments (GLORIA): *www.gloria.ac.at/res/gloria_home/*

Global Mountain Biodiversity Assessment (GMBA): *www.unibas.ch/gmba/*

Global Terrestrial Observing System (GTOS): *www.fao.org/GTOS/*

International Human Dimensions Programme on Global Environmental Change (IHDP): *www.uni-bonn.de/ihdp/*

Land-Use and Land-Cover Change (LUCC): *www.gec.ucl.ac.be/LUCC/lucc.html*

Past Global Changes (PAGES): *www.pages.unibe.ch/*

Terrestrial Ecosystem Monitoring Sites (TEMS): *www.wsl.ch/relics/rauminf/riv/datenbank/tems/database_tems.html*

*Source : Reasoner, M et. al (2001)

ENVIRONMENTAL SYSTEMS AND SOLAR ENERGY*

Environmental systems can be seen as energy systems i.e. a defined system of matter, the energy content of that matter, and the exchange of energy (which may involve the exchange of matter) between that system and its surroundings. This view of environmental systems as open energy (or thermo-dynamic) systems requires us to consider the laws of thermodynamics (i.e. energetics) which govern the transformation and transfer of energy in real process.

The First Law of Thermodynamics

The law of Conservation of Energy, or the conservation Principle. Energy cannot be created, neither can it be destroyed: energy is merely transformed from one kind of energy to another kind. This law opens the way for us to account for what happens to energy in the operation of systems, that is, it enables us to look at energy balance sheets, or energy budgets.

The Second Law of Thermodynamics

No spontaneous transformation of energy is one hundred percent efficient. In all spontaneous transformations of energy, some energy is dissipated as heat energy and is therefore unable to do work on the system.

This law imposes a direction on the operation of real processes in our systems and implies that the transfer of energy is ultimately a one-way flow from high energy levels to low energy levels. The second law prompts us to look for energy sources and energy sinks, and to look at the efficiency of individual energy transformations, in the operation of systems processes.

The solar equivalent to 5.4×10^{24} joules of energy, reaches the Earth every year. This is more than 1000 times the energy involved in any other natural process affecting the earth. Relevant information about solar energy is given below:

Summary of Solar Energy Expenditure and its likely Maximum Potential as an Energy Source*

Form of Energy Expenditure	*Total Energy Involved (J/a)*	*Maximum Potential Use (J/a)*
Direct Reflection	$1{\cdot}9 \times 10^{24}$	
Atmospheric Circulation (Winds and Waves)	$3{\cdot}0 \times 10^{23}$	$\sim 1{\cdot}0 \times 10^{20}$
Atmospheric Heating (Including dissipation of wind energy)	$1{\cdot}1 \times 10^{24}$	
Evaporation and Re-precipitation	$3{\cdot}0 \times 10^{20}$	$\sim 1{\cdot}0 \times 10^{20}$
Surface Heating	$2{\cdot}4 \times 10^{24}$	$\sim 2{\cdot}4 \times 10^{20}$
Biological Fuel (via photosynthesis)	$1{\cdot}0 \times 10^{22}$	$\sim 1{\cdot}0 \times 10^{20}$

Total solar energy income ($5{\cdot}4 \times 10^{24}$ J/a) is balanced by three main forms of energy expenditure: direct reflection ,atmospheric heating, and surface heating.

*Source: Smith, David G

ENVIRONMENTAL ETHICS

The environmental ethics traces the development of philosophy and science. The scientific knowledge should not be used as a physical power but it should consider ethical responsibilities. Environmental ethics is considered as a code of behaviour which ensures human progress without jeopardizing ecological balance. Humans are an integral part of the environment and must bear to live in harmony with nature and other fellow beings . To be able to live together in peace the basic 'ethics of all ethics is the foundation of environmental ethics. (Misra, R.P., 1992).

Various aspects of environmental ethics could serve as mirrors for checking, correcting and developing the needed ethical values and responsibilities in everyday life and in decision-making process with respect to the holistic nature of the environment, sound management and rational use of resources and protecting and improving the environment for a decent, sustainable and equitable quality of life of the present and future generations.

All ancient cultures and civilizations are founded on creative human-nature relations with built-in mechanism to correct minor ecological disturbances. Rapid industrialization and population growth have given rise to imbalances which cannot be corrected through self-correcting processes. If these forces of change are not adjusted to conform to the laws of ecology, environment , pollution and economics, poverty cannot be avoided.

Realizing the seriousness of ecological problems of today, it becomes imperative to evolve an environment sensitive value system. The environmental laws can do a lot to improve the deteriorating ecological conditions. The laws can be obeyed only if they are in tune with the value system of the people. More formal laws should be enacted to stop the rape of the natural resources of the Earth. There is need to evolve, codify and disseminate an ethical code of conduct based on judicious integration of rights and duties of individuals. Laws must support ethics and ethics the laws. Environmental ethics cannot be imposed by laws alone. It has to be articulated, systematized, codified and brought to the doorsteps of each and every individual. This needs comprehensive environment – sensitive education policy and curricula.

There is a need to integrate science and spirituality. Neither de-spiritualized science nor unscientific spirituality is the answer to the problems of the future.

Environmental ethics may be classified into two types :

(i) anthropocentric

Judo-Christian tradition gives man the stewardship of the Earth. Domination of man over the rest of the creation, forms the basis of a powerful environmental ethics. Man, therefore alone among creatures has only right to the use of creation but the responsibility to conserve and perhaps even enhance the capabilities of other creatures for self-expression, e.g. conservation of biodiversity.

(ii) Bio-centric

It is rooted in Eastern philosophies – Hinduism, Buddhism, Confucianism and Taoism. In these traditions, man was not given the stewardship of the creation. He is an integral element of 'life'. All living and non-living things have equal right to exist. Man being the supreme. creation, must use his wisdom to ensure sanctity of nature and life is preserved. (Misra, R.P. 1992)

"Vedas" are ancient revered scriptures and handed down to posterty by oral tradition for thousands of years. There are four Vedas containing a vast knowledge as revealed to great scholars 'rishis' in the depth of their medetation in Himalayas. There are four Vedas containing about 21,000 verses:

(i) Rig Veda - deals with knowledge
(ii) Yagura Veda - deals with action
(iii) Sama Veda - deals with devotion
(iv) Atharva Veda - deals with Science and Technology including agriculture, forestry social environment.

Vedic relegion has been fulcrum of ancient Indian civilisation emphasis was laid to learn the integrated and holistic approach towards maintaining the order of nature and preserving the environment.

During the Vedic Age, the seven mountains within the Indian subcontinent were mentioned as the ancient doors to Heaven. Indian thinkers reshaped these ideas and beliefs and influenced directly the thoughts and attitudes of the people. A thousand years after, the Matsya Purana (39.22) declared that 'favour, gifts, tranquility, self-control, modesty, uprightness and compassion for all creatures – these are seven doors to Heaven – so the wiseman say (Verma, R.& S, 1985). In the Bhagvad Geeta, Shri Krishna discoursing to Arjuna on the Supreme, says 'Among the mountains, I am the Himalaya'. His teachings unfold the virtues of a karmayogi, the one who performs good deeds without expecting material awards.

MILLENNIUM ISSUES*

Water

Humanity's use of freshwater soared six fold over the last century, and continues to rise. Demand is expected to increase by over a third over the next 25 years – and to almost double for drinking water. And yet it is getting scarcer. Already one-third of the world's people live in countries where water is in short supply; by 2025 two-thirds of them will do so. About one in every five people on Earth now lacks safe drinking water.

Acquifers of underground water, built up over millennia, are being exploited faster than they can be replenished; every year 160 billion tons of water are being 'mined' in this way in China, India, North Africa, Saudi Arabia and the United States alone. The water table under the north China plain, which produces 40 per cent of the country's grain harvest, is falling by 1.6 metres a year, while the International Water Management Institute estimates that the depletion of Indian acquifers could cut the country's grain harvest by a quarter. Meanwhile international tensions over shared rivers are rising, threatening water wars.

Species

Species are being driven to extinction at least 1,000 times – and may be 10,000 times – faster than they would die out naturally. No-one knows how much damage is being done, partly because no-one even knows how many species there are on Earth; estimates range from 5 million to over 100 million. But the damage is clearly accelerating. By one estimate up to two-thirds of all the species on the planet may be lost over the next 100 years. The world appears to be in the early stages of a mass extinction, to rival those of prehistoric times, the latest of which wiped out the dinosaurs. Great holes will be torn in the web of life, and countless species that could have brought great benefits to medicine and food supplies will be lost. On past evidence it will take 10 million years – far longer than the expected life span of the human species – for the planet's life to recover its diversity.

Forests

Four-fifths of the forests that originally fragmented or otherwise degraded. About 40 per cent of what is left is under threat. Some 16 million hectares of forest, an area about twice the size of Austria, are felled every year. As the trees disappear, the rainwater rushes off the land, stripping away topsoil and causing floods; it fails to percolate into the ground, causing water sources to dry up. Species become extinct, and global warming increases.

Soil

It can take anything up to 1,000 years for a couple of centimeters of topsoil to form. But increasingly this much is being washed or blown away in a few seasons. Every year the world loses some 25 billion tones of it. Some 2 billion hectares of arable and grazing land worldwide – an area larger than the United States and Mexico combined – have been moderately or severely degraded, reducing its ability to produce food. Desertification costs the world $42 billion a year in lost income and soil erosion puts the livelihoods of nearly a billion people at risk. By one estimate, crop yields in Africa could be cut in half within 40 years if degradation continues at its present rate.

Climate

The climate is getting warmer. Eight of the hottest ten years on record occurred in the last decade. Glaciers are smaller than at any time in at least 5,000 years, and the Arctic Ocean has lost 40 per cent of its ice cover in the last 30 years. Meanwhile, economic damage from disasters caused by extreme weather in 1998 alone exceeded the total for the whole of the 1980s.

The WMO/UNEP Intergovernmental Panel on Climate Change (IPCC) has concluded that, on balance, human activities are contributing to global warming, as greenhouse gases like carbon dioxide (CO_2) are emitted and forests are felled. CO_2 is now at record levels in the atmosphere. The IPCC's best prediction is that global temperatures will rise by 2° C over this century – the greatest warming in 10,000 years – while sea levels will rise by 50 centimetres, enough to flood millions of people in low-lying deltas and coastal areas and to submerge some island nations beneath the waves. Such is the inertia in the world's system that once global warming has begun, it will be very hard to stop on any reasonable time scale.

Waste

Many countries have tackled the grossest forms of pollution over the last half century. Rivers have been cleaned up and skies cleared, particularly in developed countries. But 5 million of the world's poorest people die each year from diarrhoeal diseases, largely because they lack safe water, and another 2.2 million die of respiratory conditions through burning smokey fuels in their homes. Meanwhile newer forms of pollution, such as persistent organic pollutants (which concentrate up the food chain and can be severe health effects) and endocrine disrupters (which interfere with the hormone system) are causing increasing concern.

*Source: Lean Geoffery (2000).

VISION AND ACTION PROGRAM FOR PEOPLE'S MOVEMENT FOR HIMALAYAN ECOSYSTEM REJUVENATION *

The Himalayas have been revered from times immemorial. They are the source of rivers that shaped the cultural values of India & Indians. Adorned with immense natural beauty and spectucular sites, they have been the centre of attraction for pilgrims and explorers. Many unsung Pundits devoted their lives in the mesmerism of *Nanda Devi* Countless explorers contributed to our present day understanding of the land. This divine land (*devabhumi*), is gifted with diverse flora, fauna and minerals . For example *Sanjivani*, was over and again requisitioned from this land for diverse purposes. Human greed has however subdued natural regenerative processes and many of the species are threatened and many more are extinct or are on the verge of extinction.

It is generally accepted that the natural environment of the Himalayas is deteriorating. Several theories have been put forth to explain the causes. Ironically, several of the widely accepted assumptions for the deterioration are either without factual support, or were demonstrably unsupportable (Ives & Messerli 1989) A synthesis of literature indicates some common points of different theories:

- Unprecedented population growth followed the introduction of modern health care systems after 1950
- Immigration from the plains is adding to the growing population of the hills.
- Increased population in the hills has led to :
  - ➷ Reducing amount of land per family
  - ➷ Deepening poverty
  - ➷ Massive deforestation

The impact of these factors has been described as the vicious circle, in that the needs of the burgeoning subsistence population are exerting increasing pressure on the forest cover leading to massive deforestation which is the cause of accelerating rates of mass wastage.

The deforestation, that includes cutting of agricultural terraces on steeper and more marginal mountain slopes, has led to a catastrophic increase in soil erosion, and loss of productive land through accelerated landslide incidence, and to the disruption of the normal hydrological cycle. This situation, has in turn, led to increased runoff during the summer monsoon accompanied by disastrous flooding and massive siltation in the plains, and

lower water levels and the drying up of springs and wells during the dry season. Related ills are: rapid siltation of reservoirs, abrupt changes in the courses of rivers; spread of barren sand and gravel across rich agricultural land in the plains, and increased incidence of diseases in the downstream areas. Deforestation is also perceived as the main cause for reduced rainfall.

The continued loss of agricultural lands in the mountains due to the anthropologically induced processes triggers another round of deforestation to enable the construction of more terraces on which to grow subsistence crops. Yet, as the labour of walking greater distances from the village to fuelwood supplies increases with receding forest perimeter, a critical threshold is reached whereby the available human energy (principally female) becomes progressively overtaxed and an increasing quantity of animal dung is used for fuel.

Consequently, another vicious circle is linked to the first one: terraced soils are deprived of natural fertilizer- the animal dung now being used for fuel, thus depriving the agricultural terraces, in many instances, of their only source of plant nutrients. This lowers crop yields. Also, the ensuing weakened soil structure further augments the incidence of landslides. Even more trees are cut on more marginal and steeper slopes to make room for more agricultural terraces to feed the ever-growing subsistence population.

To worsen the situation further there has been commercial cutting of the forest to meet the timber demands of the lowland population centres. Due to strategic importance, roads are being constructed in remote areas. These enhance the incidence of landslides, commercial exploitation of the resources and the movement of the population. Moreover the women become progressively overworked and under nourished and thus the next generation of children begins life more deficient in essential nutrients, so that the situation worsens further.

The entire Himalayan terrain is at present facing an acute resource management crisis. The age old traditional system of resource management has been disrupted while the alternatives put forth have proved to be far from satisfactory. People's participation that was central to the traditional system has been pushed to the corner and the little communities of the region have no option, but to be helpless spectators to the deteriorating scenario.

Despite wide variation in cultural, social and ethnological identity of the people of the Himalayan region, under- development is the common factor bringing them together. for revolt against the state. Barring a few localized centres, density of population in the region is low. This together with topographical features has hindered development of the region.

Due to the lack of industrial growth the Himalayan region is faced with out-migration of able-bodied workforce. This causes depletion of

working hands and thereby traditional industries and handicrafts of the region are dying out fast. This also adds to the drudgery of the females in the hills.

In order to improve the quality of life of the people of the region a suitable system of development involving the local populations needs to be evolved. Small scale industries, and enterpreneurship need promotion through soft loans and other incentives. At the same time marketing links need to be strengthened to ensure adequate remuneration to the artisans and entrepreneurs.

A welfare state should have been alarmed at the utter socio-economic backwardness and inequalities of the people of the Himalayan region. The entire area is ecologically sensitive and therefore warrants better consideration than it has so far received. Facilties and infrastructure have no doubt developed in the post-independence era and this is often dubbed .Length of roads, number of schools, colleges Public Health Centres, veterinary centres, and educated unemployed, are however no yardsticks for adjudging development. If at all development has to be scaled, it has to be done with regard to the improvement in the quality of life of the poorest of the poor in the region. Has infrastructural growth really added to the quality of life of the poor? Some impact has however been made upon the social, cultural an economic life of the people, be it for good or worse. Many of the gains of development have however been eroded by faulty planning, environmental degradation, deforestation, overgrazing, reckless road construction and other heavy engineering activities on the fragile Himalayan slopes.

People's participation in various developmental schemes in the region has been inadequate and often the masses are ignorant about the large number of welfare schemes launched by both central and state governments. The officials need to promote this vital connection so essential for the development of the region. Recognizing the lacunae in the policies the government is poised to change its attitude and is involving Panchayats and various voluntary organisations in the developmental work being undertaken by it. The watershed has long been recognised as the unit of development and the message of **Integrated Watershed Management** is being propagated aggressively by the officers through the years. The efforts seem to be bearing fruit and many developmental plans and endeavors are being undertaken with watershed development strategy. Voluntary agencies working in the region are busy building the confidence of the masses and it is with them that hope lies. We salute the numerous unsung heroes devoting their energies selflessly for the cause of the welfare of the people of the Himalayan region. It is their undaunted devotion towards the majestic mountains that has inspired and built a dedicated cadre of young

professionals in the voluntary sector who are busy recasting a greener, healthier and, prosperous Himalayan region. I am reproducing Himalayan Ecosystem Vision & Action Program Statement as follows :

A new state took birth on 9 November, 2000. The people of Uttaranchal look forward to a better economic and social order. The expectations are large, the challenges of being a hill state are many and concerted efforts are required both from the Government and the people to lay the foundation of a strong and vibrant economy.

The vision for the state and the Himalayan Eco System would include both human and economic development. To meet these goals, the following actions are envisioned :

I. The conservation and rejuvenation of the Himalayan environment and hence economic development should ensure that the environment is disturbed in the least possible manner and every effort is made to preserve the rich bio-diversity and unique topography of the region.

II. Improvement in the quality of life of the people, specially women, youth and children. This requires poverty eradication through income generating schemes both self employment and wage employment as well as facilities such as health, sanitation and education.

III. A land and water care movement with emphasis on **Bio-Industrial Watershed Management** is needed The on-going watershed development programmes need to be strengthened and converted into bio-industrial watershed projects by making bio-mass processing industries an integral part of watershed management. Bio industrial projects hold the promise of transforming the rural areas. Such projects would not only increase rural employment, they could also reduce out migration from region. Real income would increase and regional imbalances would decrease. Each watershed / micro watershed should be developed with local participation through

(i) Water harvesting including run off harvesting, through contour bunding or ridges; flood water harvesting through level flooded terraces, check dams for aquifer recharge , surface dams and sub surface dams.

(ii) Regeneration of water sources, particularly spring and seepages by employing the concept of "Spring Sanctuary" using physical and biological measures.

(iii) Increased agricultural productivity through the use of appropriate technologies that are profitable, labour intensive and dependable should be the major means of increasing purchasing power of the people. Proper land capability classification and its mapping on macro and micro scale is necessary for the region. Based on land classification, sustainable agriculture can be promoted which should form the basis of commercial agriculture.

Promotion of organic farming and organic food through appropriate policy interventions and, transition from food-grain based subsistence agriculture to commercial cultivation of high value- low volume crops is called for making use of comparative advantage of the microclimates.

(iv) Encouraging land based activities which are in consonance with the environment such as sericulture, horticulture and pasture development based on biofertilizers and biopesticides.

(v) Processing, marketing and quality control facilities for medicinal and aromatic plants, nuts, fruits and vegetables and milk and milk products.

IV. Renewable energy which can be used to serve the lighting, cooking and heating needs of people of the area and the small and medium industries. This includes introduction of bio-gas and high efficiency fuel wood stoves so that the pressure on forest is reduced. Further briquettes from biomass and bio-gas, ethanol, methanol can be used to meet the energy needs of the farm families. Solar technology i.e solar water heaters, solar cookers, solar crop drying and solar photo volataic cells for lighting and pumping , wind mill technology ; mini and micro hydel technologies.

V. Building up the communication system in remote areas and the use of information technology to convey the information regarding development plans and programmes to the people. Industrial development based on software development and information technology could provide an important source of livelihood to the educated youth without adverse impact on the ecology of the region. As distance and topography do not pose barriers for the latest tools in the development of information technology, the states could see themselves as a high profile technology destination

VI. The tourism potential of the Himalayan region should be utilized in full particularly in view of its scenic beauty. Various pilgrim centres should also be further developed to market the state as a destination for religious tourism. Himalayas are an inspiration and this aspect should be promoted for Eco and Religious Tourism on a large scale, sustained with efficiency and sound management principles.

VII. Awareness and organization building through Self- Help Groups, Mahilla Mangal Dals, Seed and Health Banks, Van Panchayats and Grain Banks

VIII. Involvement of the people starting from the students to the elderly through mass movement, training programs and building of local organizations including the Panchayati Raj Systems.

IX. In addition to above emphasis is to be laid on Greening of Himalayas through action programs such as follows :

(A) Greener Himalayas through Peoples Movement following tested principles and practices of Peoples Participation and Movement such as

(i) Development of Local Institutions
(ii) Promoting People's Participation by Development
(iii) Promoters by the following 8 (eight) principles such as : go to the people, live with them, learn from them, serve them, love them , plan with them, start with what they know, build on what they have
(iv) Raising the people potential
(v) Through incorporation & social energy based on ideas, ideals, friends
(vi) Training
(vii) Greater need for interaction and recommendations with the executive authorities

B. Physical Action through students also Rishi Kumars of Parmarth Niketan and others similar Spiritual, Yoga and Physical Training also by members of Mahila Mandals and Self Help Groups.

C. Himalayan Volunteers for Planting Care and Management

C1 VOLAGS/NGO Volunteers
C2 UNV - UN Volunteers - continuation of objectives of the International Year of Mountains (IYM)
C3 International Volunteers
C4 NRI (Non Resident Indian) Volunteers
C5 Trees for Life (TFL) Movement Volunteers
C6 Volunteers - Brigades in name of local leaders, dignitaries, national heros, and other distinguished persons

D. Tissue Culture Technology for Preparation for Plantlets - Plants Maturing.

1. Agrigene International
Tissue Culture Labs at various agricultural and R&D institutions
2 . Polyhouse culture for maturing plants

E. Let us Form

- Millions of Trees Clubs
- Lakhs of Trees Clubs
- Thousands of Trees Clubs

F. Aerial Seeding Program

- Muniji Task Force
- Dr. Duleep Matthai Task Force
- Pilot Commander Pravin Singh, Task Force

G. Medicinal Plants, Nurseries, Plantation Care, Semi Processing Network of NGOs e.g. Himcon –Swasthya Vatika, Chirag, Inhere, Shaikshnik Grammonnati Samiti, Swati Gramodyog

H. Involvement of Devoted and Retired Personnel

- Foresters, Agricultural Officers, Defence Officers and others for development of nurseries and manning training camps

I. Involvement of Retired Horticulturists, Hort. Stations, Nurseries, Training Institute.

J. A management and Care Taker Force

- All Girls/Females who care for all plants
- Army Eco Task Force
- Eco Monitor Society

K. Training Programs

- School and College curriculum must have Tree Planting & Greening Schedules.
- Prepare a Website - involve Media People
- All Wastelands must be planted
- National Wasteland Development Board
- Land Resources Department of Ministry of Rural Development
- Society for Promotion of Wasteland Development

L. Learn from Canada, China A Country of Trees and Forests.

Canadians - Please join, collaborate and support this Greening Movement

M. A Joint Indo Canadian Greening Himalayas Project.

A joint Indo - Japanese Greening Himalayas Project

A joint Indo - Nepalese - Indo Bhutanese Greening Himalayas

N. Plants for Greening Himalayas.

(a) High Altitude Plants (+6000ft Elevation), Deodar; Oak - Rhododendron; Nut - Fruits, Bhojpatra, Special Pines, Plain Trees (China), MAPLE, Selected Medicinal Plants

(b) Middle Level Altitude Plants (5000- 6000ft)

Nut Fruits (Almonds, Walnuts, Chest Nuts), Temperate Fruits (Peaches, Pears, Apples, Kiwi, Plums), Fuel, Fodder, Multipurpose-Mulberry, Bushes, Grasses and Legumes, Medicinal Plants, Selected Citrus plants like Lemon, Kinoo, Orange

(c) Lower Alternative plants (between 3000')

Remember SANTJI, Sanjan, Amla, Neem, Tulsi, Jamun, Imli, Sub-tropical Fruits, Mango, Litchi, Guava Lemon, Orange - Tangerine, Grapefruit, Mulberry, Selected Medicinal Plants, Bushes, Grasses, Legumes

O. Aerial Seeding though difficult is also possible and must be tried in inaccessible Areas.

To Summarize, Task of Greening & Rejuvenating Himalayas is Formidable but possible and achievable in a span of twenty or twenty five year provided all Govt, Non Govt, and People's Organization put in their commitment, devotion and physical efforts and bring out income generation through commercial Horticulture, Forestry and other plants like Medicinal & Aromatic, Nut Fruits, Vegetables, Bushes and Flowers etc.

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